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Original contribution

Effect of Boussignac continuous positive airway pressure ventilation on $Pa0_2$ and $Pa0_2/FI0_2$ ratio immediately after extubation in morbidly obese patients undergoing bariatric surgery: a randomized controlled trial☆,☆☆

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Abstract
Study Objective: Pathophysiological changes after laparoscopic Roux-en-Y gastric bypass may increase the risk of pulmonary complications in morbidly obese patients. The purpose of the study was to assess the impact of immediate postextubation use of Boussignac continuous positive airway pressure (CPAP) on arterial oxygenation in morbidly obese patients undergoing laparoscopic Roux-en-Y gastric bypass. The hypothesis is that the use of CPAP may improve oxygenation in the postoperative period when compared to Venturi mask.
Design: Randomized controlled study.

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[4] This author had a substantial contribution in design of the study and in analysis of data.
[5] This author had a substantial contribution in conception/design of the study and in acquisition of data.
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Setting: A tertiary referral hospital.
Patients: Recruited morbidly obese adult patients undergoing laparoscopic Roux-en-Y gastric bypass.
Interventions: Boussignac CPAP or Venturi mask was randomly applied immediately after extubation in the operating room and was maintained during the first 2 hours in the recovery room.
Measurements: Pa_{O_2} and Pa_{O_2}/fraction of inspired oxygen (F_{IO_2}) ratio values were measured preoperatively and at 1 (T1), 2 (T2), and 24 hours (T24) after extubation, through arterial blood samples. Secondary outcomes (spirometric parameters) were measured at the same periods. For comparison between groups, Student *t* test, Mann-Whitney *U* nonparametric test, and χ^2 test were used. Statistical significance is at $P < .05$.
Main Results: Twenty-four patients were included, 12 in each group. There were no differences in preoperative evaluation. There were significant differences between groups in Pa_{O_2} and Pa_{O_2}/F_{IO_2} mean values at T1, T2, and T24, being superior in the Boussignac group. During the 24 hours postextubation, 9% of patients in the Boussignac group and 50% in the Venturi group had a Pa_{O_2} less than 60 mm Hg in at least 1 of the evaluations. After extubation, a Pa_{O_2}/F_{IO_2} ratio value less than 300 was observed in all patients in the Venturi group and in 55% in Boussignac group in at least 1 of the evaluations. There were no differences in spirometric parameters between groups at T1, T2, and T24.
Conclusions: Application of Boussignac CPAP for 2 hours after extubation improved oxygenation but did not improve forced expiratory volume at 1 second and forced vital capacity.

1. Introduction

In 2012, the prevalence of obesity in individuals older than 18 years in Portugal was 19.9% for males and 19.8% for females [1]. Bariatric surgery has increased significantly playing an important role in the treatment of individuals with body mass index (BMI) greater than or equal to 40 kg/m^2 or less than 35 kg/m^2 in the presence of morbidity. Morbid obesity has a negative impact in the respiratory physiology. It is associated with a decreased compliance of the lung and chest wall, increased airway resistance, decreased respiratory muscle strength, increased work of breathing, impaired ventilation/perfusion ratio, and postoperative hypoxemia [2-4]. These physiologic changes are more significant due to general anesthesia and laparoscopic surgery [5,6].

Ahmad et al [7] found that morbid obesity per se, regardless of the presence of obstructive sleep apnea, was associated with increased risk of desaturation in the first 24 hours of the postoperative period.

The application of continuous positive airway pressure (CPAP) in the postoperative period seems to improve gas exchange in obese patients without increasing the risk of gastrointestinal anastomosis dehiscence [8,9]. The use of portable devices such as CPAP Boussignac may facilitate their implementation in the immediate postoperative period.

Gaszynski et al [10] found that the use of Boussignac CPAP in the postoperative period of patients undergoing bariatric surgery improved oxygen arterial pressure (Pa_{O_2}). However, they used capillary blood gas analysis not arterial blood gas analysis. The oxygen inspired fraction (F_{IO_2}) was also different between the 2 groups.

More recently, in 2011, Wong et al [11] investigated the effect of Boussignac CPAP vs Venturi mask applied during 1 hour after bariatric surgery. It was verified an improvement in the Pa_{O_2}/F_{IO_2} ratio after 1 hour postextubation but no differences in the second hour. There were no differences between the 2 groups in forced expiratory volume at 1 second (FEV1) and forced vital capacity (FVC).

In this study, it was hypothesized that a longer duration of CPAP may lead to a more sustained improvement of oxygenation in the postoperative period. Setting the same F_{IO_2} in both groups will permit a more accurate comparison of Pa_{O_2}.

The purpose of this study was to assess the impact of the use of Boussignac CPAP during 2 hours after extubation for improving Pa_{O_2} and Pa_{O_2}/F_{IO_2} ratio in morbidly obese patients submitted to laparoscopic gastric bypass surgery. As a secondary objective, we intend to evaluate if there are differences in spirometric parameters.

2. Methods

It was conducted an interventional, prospective, randomized and controlled study.

The study protocol was approved by the Health Ethics Committee (Chairperson Dr Luisa Bernardo) and the Department of Education, Training and Research of Centro Hospitalar do Porto and received institutional approval: N/REF.ª 278/13 (172-DEFI/228-CES). Trial registration: Clinicaltrials.gov under the identifier NCT 02297828.

Written informed consent was obtained by the investigator from eligible study participants the day before surgery.

2.1. Participants

Between October and November 2014, a total of 38 patients underwent laparoscopic bypass surgery in the Obesity Surgical Treatment Unit of the General Surgery Department of Centro Hospitalar do Porto, Portugal. Of them, 14 patients

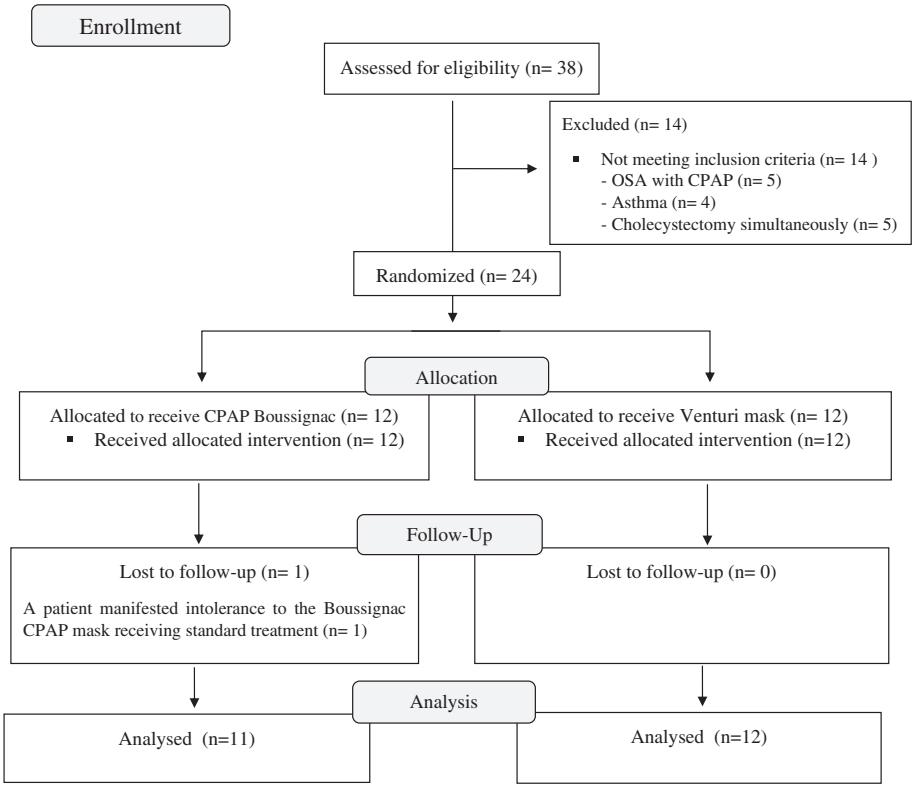

Fig. 1 Flow diagram. OSA = obstructive sleep apnea.

were excluded from our study because they did not meet the study criteria (5 patients had obstructive sleep apnea with CPAP therapy at home, 4 had asthma, and 5 were also submitted to cholecystectomy in the same procedure; Fig. 1). Twenty-four morbidly obese patients (BMI >35 kg/m^2), aged 18 to 65 years, American Society of Anaesthesiologists (ASA) class I to III, undergoing laparoscopic gastric bypass surgery were recruited by the study investigators. Patients were excluded if they had preexisting lung parenchyma disease, chronic obstructive pulmonary disease, moderate to severe asthma, obstructive sleep apnea already treated with CPAP, congestive heart failure (above class II in the New York Heart Association classification), estimated pulmonary artery pressure greater than or equal to 35 mm Hg, or hemoglobin concentration less than 7 g/dL. Patients with severe psychiatric disorder, language barrier, or anticipated need for invasive ventilation after surgery were also excluded.

2.2. Anesthetic and surgical protocol

The anesthetic protocol was provided to the attending anesthesiologist. Patients were monitored with electrocardiogram, noninvasive blood pressure, pulse oximetry, anesthetic depth monitoring (bispectral index [BIS]), and neuromuscular blockade monitoring. Ultrasound-guided arterial catheterization was performed after induction.

Drug administration was adjusted to the patients' ideal body weight (IBW = 22 × height^2) [12], to lean body mass [13] adding 20% of total body weight to the IBW, and to corrected body weight [14] adding 40% of total body weight to the IBW.

Patients were preoxygenated in a ramp position [15] (30° tilt of the upper body) applying an F_{IO_2} of 1.0 and a CPAP of around 10 cm H_2O with a face mask for 3 minutes. General anesthesia was induced with propofol 1 to 2 mg/kg and remifentanil 0.1 to 0.2 μg/kg per minute both doses based on patients' lean body mass [16,17] and with rocuronium 0.6 mg/kg based on IBW [18] (or 1.2 mg/kg if a rapid sequence induction was indicated). All patients underwent endotracheal intubation. Balanced anesthesia was maintained with desflurane and remifentanil continuous infusion, both adjusted to maintain BIS values between 40 and 60 and heart frequency and arterial pressure within 20% of baseline values. A bolus of rocuronium of 0.1 to 0.15 mg/kg was administered if a maximum train-of-four (TOF) count of 2 or higher was observed by mechanomyography.

Patients were ventilated with a controlled pressure mode (pressure-controlled volume guarantee mode) and a positive end-expiratory pressure between 6 and 10 cm H_2O (unless there was hemodynamic instability), tidal volume 6 to 8 mL/kg, and inspiratory pressure alarm set to 40 cm H_2O.

Roux-en-Y gastric bypass was performed with a pneumoperitoneum pressure between 12 and 15 mm Hg. All subjects had the same surgeon.

At the end of surgery, desflurane was discontinued, and the F_{IO_2} increased to 1.0. Remifentanil perfusion was gradually reduced and stopped after extubation. The neuromuscular

blockade was reversed with suggamadex bolus of 2 mg/kg (TOF >2) based on patient corrected body weight [14]. Extubation was performed with elevation of the upper body to 30°, with BIS value greater than 70, obeying orders and with complete reversion of neuromuscular blockade (TOF >90%). If a patient remained intubated or extubation was unsuccessful, the patient was excluded from further analysis.

For postoperative analgesia, intravenous paracetamol 1000 mg, parecoxib 40 mg, and tramadol 100-200 mg were administered 30 minutes before the end of surgery. Intravenous morphine was administered in the postanesthesia care unit (PACU) with an initial bolus of 3 mg and repeated if the patient complained of pain (with a maximum dose 0.1 mg/kg adjusted to IBW). Nausea and vomiting prophylaxis was provided by administering intravenous dexametasone 4 mg and ondansetron 4 mg. Droperidol was given as an antiemetic rescue medication in both groups.

After PACU discharge, patients received repeated doses of intravenous paracetamol 1000 mg and parecoxib 40 mg every 12 hours.

2.3. Interventions

Investigators demonstrated how to use the Boussignac CPAP mask (CPAP Boussignac; Vygon, Maia, Portugal) to all patients in the preoperative period. It was used for 5 minutes with the same parameters established for the postextubation period as described below.

Boussignac CPAP was applied immediately after extubation in the operating room. The device was connected to an oxygen cylinder with a 30 L/min flowmeter, and the flow was adjusted to obtain a 5 to 8 cm H_2O positive pressure (measured with a pressure gauge manometer connected to a side port in the valve device). A regulator device was used to set an F_{IO_2} of 0.5. Patients were transported to the PACU with the Boussignac CPAP. After arrival, the device was connected to an oxygen source close to the patient bed. Patients were positioned with a 30° elevation of the upper part of the body in both groups. Boussignac CPAP was maintained in the PACU for a period of 2 hours postextubation. Frequent pressure measurements were done to ensure a pressure delivery of 5 to 8 cm H_2O.

If at any time CPAP was intolerable, patients were treated according to the standard practices in the PACU, and the patient was excluded from further data protocol recording or analysis.

Venturi mask (OXINOVA; Carburos MEDICA, Aragon, Barcelona, Europe) was also presented to all patients during the preoperative visit by the investigator. It was applied immediately after extubation in the operating room. Patients were transported to the PACU with the device connected to the oxygen cylinder with an F_{IO_2} of 0.5. Venturi mask was maintained in the PACU for 2 hours after extubation.

The management of both devices and all the evaluations in the preoperative and postoperative periods were performed by 2 previously trained investigators.

2.4. Outcomes

The primary outcomes were Pa_{O_2} and Pa_{O_2}/F_{IO_2} ratio values after extubation. To evaluate Pa_{O_2} and Pa_{O_2}/F_{IO_2} ratio, samples for blood gas analysis were collected from radial artery and analyzed in the ABL 90 Flex Analyzer (Radiometer Medical ApS, Bronchoj, Denmark).

Samples were collected, analyzed and recorded in the preoperative period (Tpre; F_{IO_2} 0.21) before the Boussignac CPAP demonstration; in the postoperative period 1 hour after extubation (T1; F_{IO_2} 0.5) and 2 hours after extubation (T2; F_{IO_2} 0.21) in the PACU; and 24 hours after extubation (T24; F_{IO_2} 0.21) in the nursing room. After 2 hours postextubation, the device was removed, and the sample was collected with patient breathing room air for 5 minutes before sampling. Arterial samples were collected always before spirometry.

Secondary outcomes included spirometric parameters FEV1 and FVC. A portable spirometer with a mouth piece filter (Superspiro MK1 Spirometer; Micromedical/CareFusion 232 Ltd, Kent, UK) was used by 2 previously trained investigators to evaluate pulmonary function (FEV1 and FVC).

All spirometric measurements were performed with the patient in bed, positioned with a 45° elevation of the upper part of the body. The best value after 3 consecutive measurements was recorded [19]. Evaluations were done in the preoperative period (Tpre), in the postoperative period 1 hour (T1) and 2 hours (T2) after extubation in the PACU, and 24 hours (T24) after extubation in the nursing room.

The level of sedation (Ramsay scale), postoperative pain (verbal categorical rating scale), and total dose of morphine were recorded in the PACU. Patients were discharged from the PACU if discharge criteria were met.

Postoperative complications, reintubation, intensive care unit (ICU) admission, and length of hospital stay were recorded.

2.5. Blinding and randomization

Randomization using a computer-generated number list was used to allocate patients.

The attending anesthesiologist was blinded until the end of surgery. Before extubation, the sealed randomization envelope was opened by the investigator, and the patient was allocated either to the Boussignac group or the Venturi group.

2.6. Sample size and statistical analysis

Based on a previous study [10], a difference of 15 mm Hg between groups was considered significant (SD, 8.2 mm Hg) for Pa_{O_2}. Assuming an α of .05, a sample of 18 patients (9 in each group) would result in a power of 95%. Given an anticipated dropout of 20%, a final sample of 24 patients was obtained (12 in each group).

Statistical analysis was performed using IBM SPSS statistics version 22. Categorical variables are presented as

frequency and percentage, and continuous variables are presented as mean ± SD and median (minimum-maximum). Variables were tested for normal distribution using the Shapiro-Wilk test. For comparison between groups, the Student *t* test was used for normally distributed continuous variables (Levene's test for homogeneity of variances), the Mann-Whitney *U* nonparametric test was used for nonnormally distributed continuous variables; and the χ^2 test for categorical variables. Friedman nonparametric 2-way analysi of variance was used for comparison within each group. Values higher than 2 SDs were considered data recording artifacts and removed from the analysis. $P < .05$ was considered to be statistically significant.

3. Results

Twenty-four patients were randomly assigned from October to November 2014. All patients were successfully extubated in the end of surgery.

A patient in the Boussignac group demonstrated intolerance to the device in the first minutes after extubation. The patient was transferred to the standard clinical care protocol, the data recording protocol stopped, and he/she was excluded from the analysis (Fig. 1).

Group analysis included 11 patients in Boussignac group and 12 patients in Venturi group. There were no differences between groups in patients' baseline characteristics and preoperative measurements of variables considered in primary (Pa_{O_2} and Pa_{O_2}/F_{IO_2} ratio) and secondary outcomes (FEV1 and FVC) (Tables 1 and 2).

Pa_{O_2} and Pa_{O_2}/F_{IO_2} mean values 1 hour (T1), 2 hours (T2), and 24 hours (T24) after extubation were superior in the Boussignac group (Table 2).

Mean values of Pa_{O_2}/F_{IO_2} ratio less than 300 occurred at T1 in the Boussignac group and at T1 and T2 in the Venturi group (Fig. 2). During the 24 hours postextubation, 55% (n = 6) of patients in Boussignac group had a Pa_{O_2}/F_{IO_2} ratio value less than 300 in at least 1 of the evaluations. In the Venturi group, all patients (n = 12) had a ratio less than 300 in at least 1 of the evaluations 24 hours after extubation. Regarding Pa_{O_2}, values less than 60 mm Hg occurred only in the postoperative period (Fig. 3). During the 24 hours postextubation, 9% of patients (n = 1) in the Boussignac group and 50% of patients (n = 6) in the Venturi group had a Pa_{O_2} less than 60 mm Hg in at least 1 of the evaluations.

Within each group, Pa_{O_2}/F_{IO_2} and Pa_{O_2} values had significant differences comparing Tpre, T1, T2, and T24 (Figs. 2 and 3). In the CPAP group, there is a significant difference in Pa_{O_2}/F_{IO_2} ratio between Tpre and T1 ($P = .006$, adjusted *P* value for multiple comparisons). No differences from T1 to T2 ($P > .999$, adjusted *P* value for multiple comparisons) and from T2 to T24 ($P = .592$, adjusted *P* value for multiple comparisons). In the Venturi group, there is a significant difference in Pa_{O_2}/F_{IO_2} ratio from Tpre to T1 ($P < .001$ adjusted *P* value for multiple comparisons) and from T1 to T2 ($P = .034$, adjusted *P* value for multiple comparisons). No differences between T2 and T24 ($P > .999$, adjusted *P* value for multiple comparisons).

Table 1 Baseline characteristics of patients.

Variables	Boussignac group	Venturi group	*P*
Age (y)	41.82 ± 6.98	44.75 ± 12.28	.486
Gender (M/F)	1/10	3/9	.315
Weight (kg)	111.82 ± 17.16	116.38 ± 18.33	.546
Height (m)	1.60 ± 0.07	1.64 ± 0.06	.260
BMI (kg/m^2)	43.35 ± 5.56	43.49 ± 6.49	.956
ASA classification (2/3)	10/1	12/0	.286
Comorbid conditions	10	12	.286
Cardiovascular	8	8	
Respiratory	2	1	
Endocrine	8	9	
Mallampati score			.542
I	4	2	
II	6	9	
III	1	1	
IV	0	0	
Neck circumference (cm)			.510
<40	7	6	
>40	4	6	
Time of surgery (min)	120.00 (87-133)	108.00 (81-324)	.316 [a]

F = female; M = male.

Data are presented as frequency or mean ± SD or median (mininum-maximum).

[a] Nonparametric test.

Table 2 Primary and secondary outcomes

Variables	Boussignac group	Venturi group	*P*
Preoperative (baseline) data			
Pa_{O_2}/F_{IO_2} 0.21	412.46 ± 63.94	393.53 ± 78.35	.535
Pa_{O_2} (mm Hg)	86.62 ± 13.43	82.64 ± 16.45	.535
Pa_{CO_2} (mm Hg)	35.5 (30.6-43.9)	36.7 (33.1-44.3)	.316 [a]
A-a gradient	26.06 ± 10.02	27.13 ± 13.53	.841
FEV1	2.41 ± 0.29	2.33 ± 0.62	.700
FVC	2.61 ± 0.32	2.57 ± 0.69	.862
FEV1/FVC	0.92 ± 0.05	0.91 ± 0.08	.531
Postoperative data T1			
Pa_{O_2}/F_{IO_2} 0.5	257 (129.8-498)	192.3 (107.4-230)	.013 [a]
Pa_{O_2} (mm Hg)	128.5 (64.9-249)	96.15 (53.7-115)	.013 [a]
Pa_{CO_2} (mm Hg)	41.32 ± 4.24	44.89 ± 5.28	.090
A-a gradient	151.6 (30.1-246.7)	206.25 (189.8-250.8)	.113 [a]
FEV1	1.44 ± 0.28	1.33 ± 0.60	.577
FVC	1.67 ± 0.32	1.47 ± 0.58	.300
FEV1/FVC	0.87 ± 0.10	0.90 ± 0.10	.485
Postoperative data T2			
Pa_{O_2}/F_{IO_2} 0.21	358.74 ± 39.16	294.68 ± 42.94	.001
Pa_{O_2} (mm Hg)	75.34 ± 8.22	61.88 ± 9.02	.001
Pa_{CO_2} (mm Hg)	40.13 ± 3.50	43.68 ± 4.22	.040
A-a gradient	30 (17.8-43.9)	38.6 (29.5-92.4)	.16 [a]
FEV1	1.58 ± 0.20	1.41 ± 0.50	.324
FVC	1.82 ± 0.25	1.51 ± 0.51	.085
FEV1/FVC	0.86 (0.64-0.98)	0.96 (0.76-0.99)	.047 [a]
Postoperative data T24			
Pa_{O_2}/F_{IO_2} 0.21	379.26 ± 43.70	308.97 ± 28.82	<.001
Pa_{O_2} (mm Hg)	79.64 ± 9.18	64.88 ± 6.05	<.001
Pa_{CO_2} (mm Hg)	38.51 ± 3.53	41.39 ± 3.28	.055
A-a gradient	27.79 ± 7.93	37.67 ± 6.45	.006
FEV1	1.89 ± 0.38	1.66 ± 0.55	.261
FVC	2.07 ± 0.42	1.82 ± 0.58	.248
FEV1/FVC	0.92 (0.8-0.99)	0.97 (0.67-0.99)	.928 [a]

Data are presented as frequency or mean ± SD or median (mininum-maximum).
[a] Nonparametric test.

Results of other blood gas analysis variables showed that alveolar-arterial gradient (A-a gradient) was significantly lower in the Boussignac group at T24 (Table 2).

Analysis of secondary outcome variables (FEV1 and FVC) showed no differences between groups at T1, T2, and T24 (Table 2).

There were no differences between groups in other variables registered in the postoperative period (Table 3).

4. Discussion

Pa_{O_2} and Pa_{O_2}/F_{IO_2} ratio were higher in the Boussignac group at 1 and 2 hours postextubation in this study.

Gaszinsky et al [10] compared the application of Boussignac CPAP mask with nasal catheter in morbidly obese patients undergoing bariatric surgery showing significant differences in Pa_{O_2} at 30 minutes, 4 hours, and 8 hours after extubation. The F_{IO_2} in both groups was not determined; therefore, the observed differences in Pa_{O_2} may be not related to the CPAP effect. Values of Pa_{O_2} were obtained from capillary samples which are not as accurate as arterial blood samples. In addition, the interventions were maintained during all evaluations not determining if Boussignac CPAP could have a prolonged benefit after its discontinuation. More recently, in 2011, Wong et al [11] compared the effect on Pa_{O_2}/F_{IO_2} ratio of Boussignac CPAP mask vs Venturi mask. Both were applied for 1 hour with significant improvement in Pa_{O_2}/F_{IO_2} ratio 1 hour after extubation. At 2 hours, there were no differences. The F_{IO_2} was variable in the Boussignac CPAP mask. Because F_{IO_2} was higher in this group, differences in the Pa_{O_2} values were influenced by this factor and not only by a positive effect of CPAP on ventilation/perfusion matching. In our study, the same F_{IO_2} was used in both groups to compare Pa_{O_2} values and to evaluate with more reliability the impact of CPAP on gas exchange and ventilation/perfusion matching immediately after extubation. We also prolonged the intervention for 2 hours. Mean values of Pa_{O_2} and Pa_{O_2}/F_{IO_2} ratio at 1, 2, and 24 hours after extubation were significantly higher in the Boussignac group. The use of Boussignac

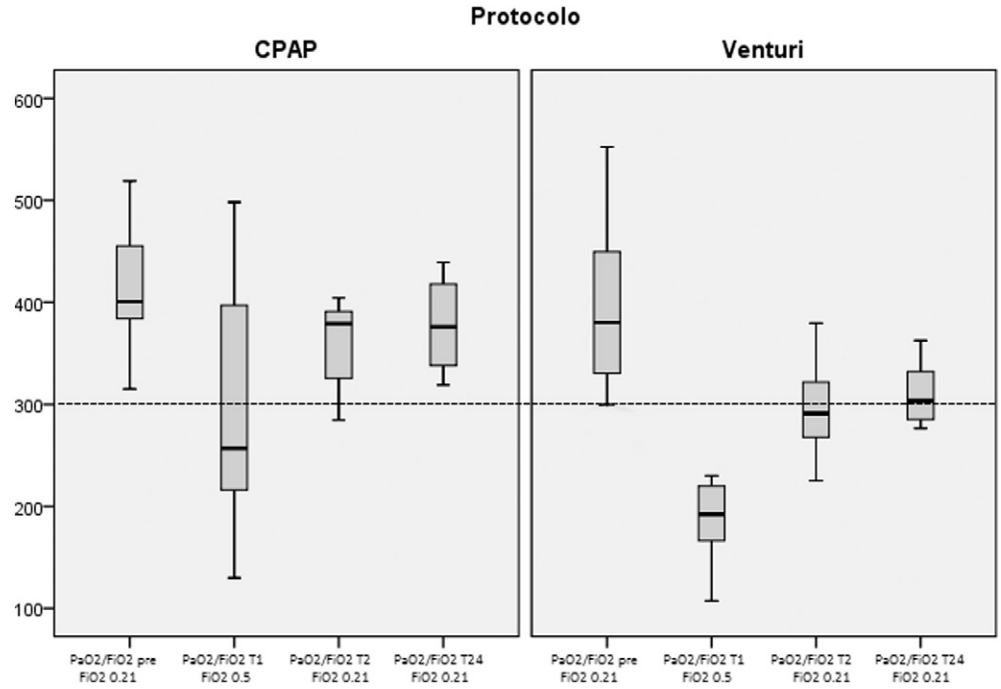

Fig. 2 Distribution of the Pa_{O_2}/F_{IO_2} ratio in Boussignac CPAP and in Venturi groups preoperatively (Tpre) and during the evaluations at 1 (T1), 2 (T2), and 24 (T24) hours after extubation (Friedman nonparametric 2-way analysis of variance: Boussignac group $P = .003$; Venturi group $P < .001$). Dashed line (—) separates Pa_{O_2}/F_{IO_2} ratio values under and upper 300.

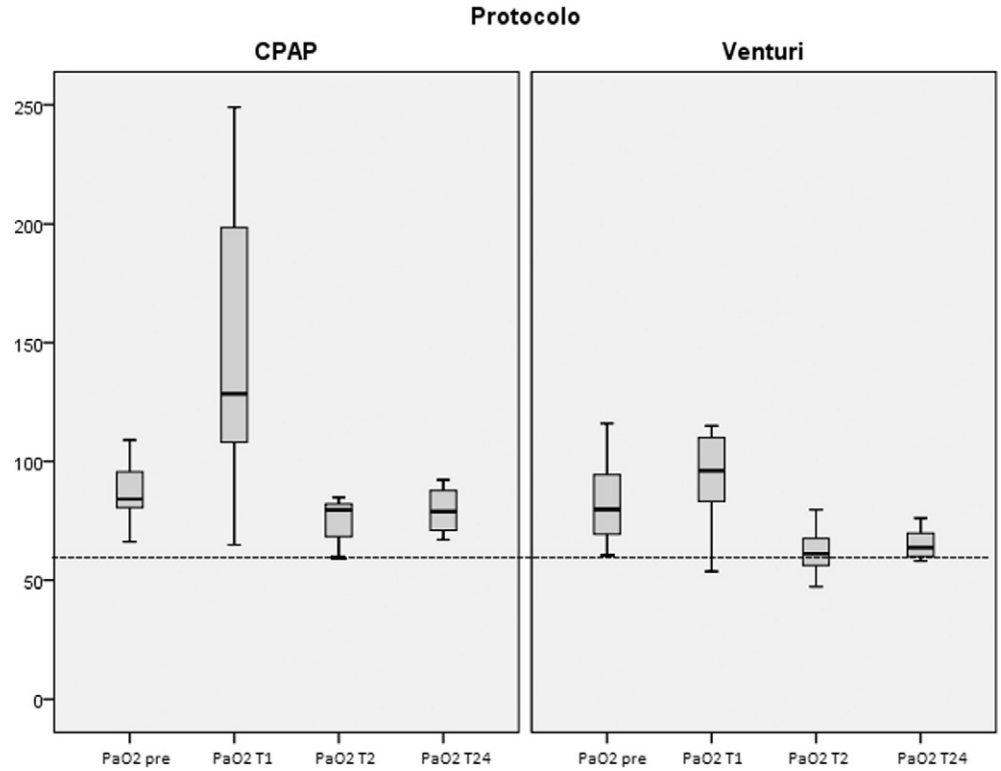

Fig. 3 Distribution of the Pa_{O_2} values (millimeters of mercury) in Boussignac CPAP and in Venturi groups preoperatively (Tpre) and during the evaluations at 1 (T1), 2 (T2), and 24 (T24) hours after extubation (Friedman nonparametric 2-way analysis of variance: Boussignac group $P < .001$; Venturi group $P < .001$). Dashed line (—) separates Pa_{O_2} values under and upper 60 mm Hg.

Table 3 Perioperative data

Variables	Boussignac group	Venturi group	*P*
Total morphine at PACU (mg)	6 (3-10)	6 (3-9)	.651 [a]
Pain evaluation, PACU T1			.587
No pain	4	2	
Mild pain	5	5	
Moderate pain	2	3	
Intense pain	0	1	
Severe pain	0	1	
Pain evaluation, PACU T2			.305
No pain	6	4	
Mild pain	5	8	
Moderate/intense/severe	0	0	
Ramsay sedation scale, PACU T1			–
Level 2	11	12	
Other levels (1/3/4/5)	0	0	
Ramsay sedation scale, PACU T2			–
Level 2	11	12	
Other levels (1/3/4/5)	0	0	
Reintubation	0	0	–
Postoperative complications	0	1 [b]	.328
ICU admission	0	0	–
Length of hospital stay (d)	3 (3-4)	3 (3-4)	.976 [a]

Data are presented as frequency or mean ± SD or median (mininum-maximum).

[a] Nonparametric test.

[b] Wound infection at trocar insertion site.

CPAP for at least 2 hours after extubation resulted in oxygenation improvement until 24 hours.

Regarding the clinical importance of our results, we found that all patients in the Venturi group presented respiratory insufficiency (Pao_2/FIO_2 <300) in at least 1 of the postoperative evaluations while in the Boussignac group that occurred in 55%. Risk of tissue hypoxia due to a Pao_2 less than 60 mm Hg was also more frequent in the Venturi group. In both groups, Pao_2/FIO_2 ratio decreased significantly from Tpre to T1; however, mean values at T1 were higher in the CPAP group. The mean value of T1 has fulfilled the criteria of respiratory insufficiency only in Venturi group. From T1 to T2, Pao_2/FIO_2 values have improved but still significantly less than in the CPAP group.

Results of alveolar-arterial gradient revealed that patients in the Boussignac group had a significant difference in gradient 24 hours after extubation, and this finding may be an indicator of a better ventilation/perfusion matching. Morbidly obese patients develop more atelectasis during anesthesia which frequently persist 24 hours after surgery, whereas it completely resolve in nonobese patients [20]. Because we have found a lower alveolar-arterial gradient in the Boussignac group, the application of CPAP immediately after extubation may have a positive effect in the prevention of additional atelectasis after surgery.

We observed an important dispersion of Pao_2 values in the Boussignac group after the first hour (Fig. 3) which may indicate that some patients may benefit of adjustments on the CPAP level to optimize ventilation/perfusion matching.

FEV1 and FVC tend to decrease with increasing BMI, and the FEV1/FVC keeps well preserved because the major effect is a restrictive ventilation pattern not airway obstruction [21]. After anesthesia and laparoscopic surgery, pulmonary function is even more compromised [22]. Considering the effect of CPAP on pulmonary function after bariatric surgery, we did not find significant differences between groups in FEV1 and FVC. Neligan et al [23] compared the ventilatory effects of Boussignac CPAP immediatly after extubation vs the application of CPAP 30 minutes after extubation in the recovery room. The CPAP ventilation was maintained for 8 hours after surgery in all patients. Authors concluded that early use of CPAP preserved better the pulmonary function. Other studies evaluated the use of positive pressure bilevel in morbidly obese patients observing better outcomes in oxygen saturation, FEV1, and FVC until 24 hours after surgery [8,24,25]. In our study, patients were exposed to CPAP only for 2 hours which may be insufficient to have a significant improvement in spirometric parameters. It is also possible that patients may have a better benefit on pulmonary function with the use of inspiratory pressure support.

Regarding possible effects of other variables in the results, patients were all submitted to the same surgery, and the mean surgery times were similar between groups. Opioid consumption, level of pain, and sedation may also influence the ventilatory pattern and pulmonary function [26]. These factors were evaluated and presented no differences between groups.

This study presents some limitations. It is a single-center study, conducted in a hospital with an obesity surgical treatment unit. Most patients were women, reflecting the demographics of bariatric surgery patients. There is the possibility of different outcomes if more men were enrolled because central obesity is more frequent in men and it has a negative impact in respiratory physiology [27-29].

In conclusion, application of Boussignac CPAP for at least 2 hours after extubation improved oxygenation, and this effect is sustained for 24 hours.

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