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Continuous Positive Airway Pressure via *the Boussignac System Immediately after Extubation Improves Lung Function in Morbidly Obese Patients with Obstructive Sleep Apnea Undergoing Laparoscopic Bariatric Surgery*

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Background: **Morbidly obese patients are at elevated risk of perioperative pulmonary complications, including airway obstruction and atelectasis. Continuous positive airway pressure may improve postoperative lung mechanics and reduce postoperative complications in patients undergoing abdominal surgery.**

Methods: **Forty morbidly obese patients with known obstructive sleep apnea undergoing laproscopic bariatric surgery with standardized anesthesia care were randomly assigned to receive continuous positive airway pressure *via* the Boussignac system immediately after extubation (Boussignac group) or supplemental oxygen (standard care group). All subjects had continuous positive airway pressure initiated 30 min after extubation in the postanesthesia care unit *via* identical noninvasive ventilators. The primary outcome was the relative reduction in forced vital capacity from baseline to 24 h after extubation.**

Results: **Forty patients were enrolled into the study, 20 into each group. There were no significant differences in baseline characteristics between the groups. The intervention predicted less reduction in all measured lung functions: forced expiratory volume in 1 s (coefficient 0.37, SE 0.13, $P = 0.003$, CI 0.13–0.62), forced vital capacity (coefficient 0.39, SE 0.14, $P = 0.006$, CI 0.11–0.66), and peak expiratory flow rate (coefficient 0.82, SE 0.31, $P = 0.008$, CI 0.21–0.1.4).**

Conclusions: **Administration of continuous positive airway pressure immediately after extubation maintains spirometric lung function at 24 h after laparoscopic bariatric surgery better than continuous positive airway pressure started in the postanesthesia care unit.**

MORBIDLY obese (MO) patients are at elevated risk for perioperative pulmonary complications. These include increased atelectasis, due to loss of functional residual capacity (FRC), anesthesia, and surgery and airway obstruction consequent of obstructive sleep apnea-hypopnea syndrome, anesthesia, and opioid analgesia.[1–3] A variety of techniques have been applied to minimize the development of perioperative atelectasis, including reverse Trendelenberg positioning, intraoperative positive end expiratory pressure (PEEP), and continuous positive airway pressure (CPAP) during induction of anesthesia. However, the period immediately after extubation is a potentially hazardous time due to the risks of airway obstruction, narcosis, residual anesthesia, and residual neuromuscular blockade.

CPAP is widely used to reduce the risk of airway obstruction in postoperative bariatric surgery patients with known obstructive sleep apnea.[4] In our institution, these patients are administered CPAP in the recovery room within 1 h after extubation, and this is continued overnight. CPAP may have a secondary beneficial effect in terms of improving postoperative lung mechanics.[5–8] However, the optimal timing of the use of CPAP remains unclear. We hypothesized that the maintenance of positive airway pressure immediately after extubation and during transit to the postanesthesia care unit, as opposed to CPAP commenced in the recovery room, would result in a significant improvement in lung function as measured by spirometry.

The application of CPAP by facemask during transport is limited by the requirement to deliver high-flow oxygen to the patient, conventionally through a CPAP facemask or a noninvasive ventilator. Neither technology is widely available, and the latter is expensive, requiring a ventilator that will run on batteries and gas cylinders. The Boussignac CPAP system uses moderate oxygen flow rates (20–25 l/min) and can easily be used for patient transport.[9,10]

The objective of this study was to determine whether immediate, postextubation, CPAP (administered using the Boussignac system) improves lung function as assessed by spirometry 1 h and 24 h after extubation, compared with CPAP started in the recovery room, in MO patients with obstructive sleep apnea undergoing laparoscopic bariatric surgery. The primary outcome was the relative reduction in forced vital capacity (FVC) from baseline to 24 h after extubation.

Materials and Methods

Methodology

After approval from the institutional review board (Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania), all patients were consented for inclusion in the study. A single blinded investigator (GM) recorded

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Table 1. Standardized Approach to Anesthesia Used in this Study

Induction of anesthesia
Ramped position
Preoxygenation with pressure support 7–10 cm H_2O/PEEP 10 cm H_2O
Intravenous induction with fentanyl/propofol/vecuronium
Direct view laryngoscopy
Maintenance of anesthesia
Reverse Trendelenberg position
Volume-controlled ventilation
Tidal volume 6 ml/kg ideal body weight
PEEP 7 cm H_2O if BMI $<$ 50 and 10 cm H_2O if BMI $>$ 50
Oxygen (50%), air, desflurane
Vecuronium
Morphine and ketoralac for analgesia
Emergence from anesthesia
Reversal of neuromuscular blockade
Extubation in semirecumbent position
Transfer to stretcher and recovery in semirecumbent position
Postanesthesia care unit/ward
Application of CPAP determined by preoperative sleep study
Hydromorphone PCA
All patients remained in recovery for 2 hours before admission to bariatric care unit
CPAP therapy for minimal 8 hours overnight

BMI = body mass index; CPAP = continuous positive airway pressure; PCA = patient controlled analgesia; PEEP = positive end expiratory pressure.

all data and took all measurements. Before commencement of the study, this investigator was trained in the performance of spirometry in the pulmonary function testing laboratory of the Hospital of the University of Pennsylvania. Forty patients with polysomnography-defined obstructive sleep apnea-hypopnea syndrome and undergoing laparoscopic gastric bypass surgery were randomly assigned to immediate postextubation CPAP using the Boussignac system (Boussignac group, BG) or CPAP commenced 30 min after extubation in the postanesthesia care unit (standard group, SG).

In the preoperative area, the spirometry process was described and shown to the subjects. A nose clip was placed and a Viasys Micro Lab spirometer (Micro Medical Ltd, Chatham, Kent, United Kingdom) with a MicroGard® microbial filter was used by the bedside to obtain the preoperative spirometry results. Three spirometry attempts we made at each measurement, and the best value recorded preoperatively at 1 h and 24 h postoperatively. FVC, forced expiratory volume in 1 s (FEV_1), and peak expiratory flow rate (PEFR) were measured and recorded at each time point.

All subjects had the same surgeon. All subjects underwent general anesthesia using a standardized approach based on a preexisting evidence-based clinical practice guideline (table 1): preinduction CPAP/Pressure Support (7–10 cm H_2O/10 cm H_2O) administered *via* the anesthesia machine (Fabius GS®; Dräger North America, Telford, PA),[11] positioning in the ramped position (with the external auditory meatus located at the level of the anterior chest wall),[12] induction with fentanyl (1–1.5 μg/kg), propofol (1–2 mg/kg), vecuronium (0.1 mg/kg total body weight), direct view laryngoscopy, oxygen (F_{IO_2} 50%), air, desflurane, and vecuronium for maintenance anesthesia and intraoperative PEEP.[13] Patients with a body mass index of less than 50 received 7 cm H_2O PEEP, and patients with a body mass index of greater than 50 received 10 cm H_2O PEEP. Patients received volume-controlled ventilation, with a tidal volume of 6 ml/kg ideal body weight, and a respiratory rate of 12 breaths per minute.

Intraoperatively, a recruitment maneuver (40 cm H_2O for 30–40 s)[14] was performed immediately after intubation. All patients received morphine 0.1 to 0.2 mg/kg of adjusted body weight (adjusted body weight = ideal body weight + 0.25(total body weight − ideal body weight)) and 30 mg of ketoralac for intraoperative analgesia. All patients were extubated in the semirecumbent position after complete reversal of neuromuscular blockade. Subjects were not permitted to breathe spontaneously under anesthesia. After reversal, patients were extubated if they were able to obey commands and were taking tidal volumes of at least 400 ml with a respiratory rate of fewer than 20 breaths per minute.

The SG subjects were extubated to nasal cannulae with 4–6 l/min oxygen. The BG subjects were extubated and immediately placed on the Boussignac CPAP system (Vitaid, Toronto CA) attached to oxygen cylinders delivering 25 l/min. This delivers approximately 10 cm H_2O of CPAP. This was confirmed in a series of volunteers before commencing the study by attaching a manometer to the side port of the device and adjusting the flow rate. These subjects received this ventilatory support during transport to the postanesthesia care unit (PACU) and in the PACU until changed to standard postoperative CPAP.

All subjects were moved from the operating room table to their bariatric bed in the semirecumbent position and transported to the PACU. On arrival to the PACU, all subjects were connected to standard monitors, analgesia was administered *via* a patient-controlled analgesia device that administered 0.125 mg of IV bolus hydromorphone with a 6-min lockout period. Thirty minutes after extubation, all subjects received CPAP using a full facemask with pressure settings prescribed from their sleep study. CPAP was delivered using the same device (BiPAP Vision®; Respironics, Murraysville, PA). CPAP was discontinued in all patients 1 h after extubation for performance of spirometry, restarted for the duration of the patients' 2-hour stay in PACU, and continued on the postoperative night for a minimum of 8 h.

Measurements

The Boussignac system was removed from the patient care location before the investigator being called back to perform spirometry. All of the patients were receiving

CPAP from a BiPAP Vision® device at 1 h postoperative. This was discontinued for 5 min before spirometry, and the patient was given 4 l of oxygen by nasal cannulae, and Spo_2 was noted. Supplemental oxygen was discontinued briefly for spirometry. The subjects performed three forced spirometry attempts. The maximal FEV_1, FVC, and PFER were recorded. The last recorded heart rate and blood pressure readings were also noted. The subjects were then restarted on CPAP for the duration of their PACU stay. Spirometry was repeated 24 h after extubation by using the same methodology, and Spo_2 was again noted.

Study Objectives

The objective of this study was to determine (1) whether MO patients lose significant lung volume in the first postoperative hour, (2) whether the application of CPAP immediately after extubation prevents this loss of lung volume, and (3) whether CPAP commenced 1 h postoperatively recovers lost lung volume. The primary outcome was FVC at 24 h after extubation.

Secondary outcome measures included FEV_1, FVC, and PEFR at 1 and 24 h, the number of episodes of hypoxemia ($Spo_2 < 92\%$), reintubation, requirement for naloxone, unplanned admission to intensive care, cardiac or respiratory arrest, and death.

Sample Size

Based on previous studies in the obese and nonobese population,[1,2,7,8,15–17] it was expected that the BG would exhibit a 30% greater retention in their 1-day postoperative FVC (measured as a percentage of baseline) than the SG. Assuming an alpha of 0.05 (*i.e.*, significant at $P < 0.05$), 16 patients each in the control and intervention groups would result in a beta (power) of 86%. Twenty subjects in each group were enrolled to ensure 16 evaluable subjects.

Randomization

Patients were randomized into four groups by using sealed envelopes, depending on the surgical operation that they would undergo: 20 patients were randomized to Boussignac CPAP, of which 10 underwent laparoscopic gastric banding and 10 underwent hand-assisted laparoscopic roux-en y gastric bypass; 20 patients were randomized to the standard care group, of which 10 underwent laparoscopic gastric banding and 10 underwent laparoscopic roux-en y gastric bypass. The study group assignment was revealed to the clinical anesthesiologist who was managing the patient in the operating room moments before extubation.

Statistical Analyses

Proportional data were examined by chi-square analysis or Fisher exact test where cell values are below 5. Nonnormally distributed (nonparametric) data were analyzed with the Mann–Whitney U test. Normally distributed data were analyzed using Student *t* test for pairwise comparison. Spirometry values were tested for skewness and kurtosis and determined to be normally distributed. Because there were 3 measurements made over time, we developed a generalized linear model to determine the effect of time and possible confounders upon the relationship of intervention to spirometric outcome. Confounders of the relationship between spirometry values and group status were examined starting with univariate predictors and building in the *a priori* identified potential confounders: gender, age, height, body mass index, and apnea-hyponea index. We chose to present both the generalized linear model data and then the direct comparisons of time points *via t* tests because the generalized linear model shows the validity of the effect of the intervention over time and the *t* test presents the data in a clear and clinically relevant format.

Results

Forty patients were considered for study enrollment. All consented and were randomized, 20 into each group. There were no differences in baseline variables between the groups (table 2). There were no differences in baseline FEV_1 (mean 2.47 in BG *vs.* 2.42 in SG, $P = 0.7$), FVC (mean 2.89 *vs.* 2.84, $P = 0.9$), or PEFR (mean 5.96 *vs.* 5.88, $P = 0.9$) between the groups at preoperative measurement (table 3).

The generalized linear model indicated that the intervention predicted less reduction in all measured lung functions than standard care (table 4): FEV_1 (coefficient 0.37, SE 0.13, $P = 0.003$, CI 0.13–0.62), FVC (coefficient 0.39, SE 0.14, $P = 0.006$, CI 0.11–0.66), PEFR (coefficient 0.82, SE 0.31, $P = 0.008$, CI 0.21–0.1.4) (see table 4). In examining univariate predictors of the spirometric lung functions, age negatively affected FEV_1 (coefficient −0.01, SE 0.005, $P = 0.024$ CI −0.025–0.002) but not FVC or PERF. As expected, Height predicted FEV_1 (coefficient 3.9, SE 0.63, $P < 0.001$, CI 2.66–5.15), FVC (coefficient 4.61, SE 0.69, $P < 0.001$, CI 3.23–5.97), and PERF (coefficient 6.64, SE 1.65, $P < 0.001$, CI 3.42–9.87). Weight did not predict lung volumes, and body mass index weakly negatively predicted FVC (coefficient −0.028, SE 0.013, $P = 0.030$, CI −0.05–0.002) but not FEV_1 or PERF. Sex had no impact on lung volumes. In developing the multivariate generalized linear model, the impact of the intervention was not altered by height (or *vice versa*). The effect of age was eliminated by including height. Weight, body mass index, and sex did not confound the relationship between intervention and spirometric value, nor did they impact the effect of height.

One hour after arrival in PACU, all subjects had a statistically significant reduction in pulmonary function

Table 2. Baseline Characteristics of Patients

	Standard Care Group, Mean (Range)	Boussignac Group, Mean (Range)	Statistical Significance
Gender	80% female	75% female	NS
Age, yr	47.5 (18–66)	46.9 (37–63)	NS
Weight, kg	133.00 (99.8–186.9)	133.56 (117.9–177.8)	NS
Height, m	1.67 (1.55–1.82)	1.68 (1.53–1.83)	NS
Body mass index, kg/m^2	47.4 (41–59)	46.3 (39–54.2)	NS
ASA physical status	2.5 (2–3)	2.6 (2–3)	NS
ASA 2	9	8	
ASA 3	11	12	NS
Apnea hypopnea index	42.0 (10–93)	50.0 (10–129)	NS
CPAP setting cm H_2O (sleep study)	10.0 (4–17)	10.0 (8–13)	NS
Surgery, gastric bypass/band	10/10	10/10	—
Intraoperative tidal volume, ml	650 (450–820)	664 (550–800)	NS
Intraoperative PEEP, cm H_2O	8.5	8.6	NS

ASA = American Society of Anesthesiologists; CPAP = continuous positive airway pressure; PEEP = positive end expiratory pressure.

test values from baseline, with BG group having clinically and statistically significantly better preservation of preoperative function (table 3). FEV_1 in SG was reduced 52% from baseline *versus* 27% in BG ($P = 0.01$), FVC was reduced by 50% from baseline in SG *versus* 27% in BG ($P = 0.01$), and PEFR was reduced by 62% from baseline in SG *versus* 42% in the BG ($P = 0.01$). There were statistically significant differences between the groups for the absolute value of all measures: FEV_1 for SG was 1.16 l *versus* 1.80 l for BG ($P = 0.001$), FVC for SG was 1.42 l *versus* 2.11 l for BG ($P = 0.001$), and PEFR for SG was 2.26 l *versus* 3.48 l in BG ($P = 0.001$).

Both groups received postoperative CPAP for the duration of their stay in PACU and for at least 8 hours overnight. The mean CPAP level in both groups was 10 cm H_2O (range 5–17 SG, range 7–13 BG). There were no differences in the hours of postoperative CPAP.

On the first postoperative morning, all subjects continued to have a statistically significant reduction in pulmonary function tests from baseline, with BG continuing to have significantly better preservation of lung volume (table 3). FEV_1 in SG was reduced 42% from baseline *versus* 26% in BG ($P = 0.01$), FVC was reduced by 42% from baseline in SG *versus* 27% in BG ($P = 0.04$), and

Table 3. Results

				Reduction from Baseline %	
	BG	SG	*P*	BG	SG
Preoperative (baseline) data					
FEV1	2.47	2.42	0.7		
FVC	2.89	2.84	0.9		
PEFR	5.96	5.88	0.9		
1 h postoperative data					
FEV1	1.80	1.16	0.01	−27	−52
FVC	2.11	1.42	0.01	−27	−50
PEFR	3.48	2.26	0.01	−42	−62
1 day postoperative data					
FEV1	1.82	1.41	0.01	−26	−42
FVC	2.10	1.66	0.04	−27	−42
PEFR	4.26	3.33	0.05	−29	−44

Spirometeric data are reported as mean. Reduction from baseline refers to the percentage reduction in spirometry values from the preoperative (baseline) values. BG had significantly better spirometry 1 hour and 1 day postoperatively.

BG = Boussignac CPAP group; FVC = forced vital capacity; FEV1 = forced expiratory volume in 1 second; PEFR = peak expiratory flow rate; SG = standard care group.

Table 4. Results of Generalized Linear Model Analysis

	Coefficient	SE	*P*	CI
Univariate				
FEV1				
Intervention	0.37	0.13	0.003	0.12–0.61
Age	−0.13	0.006	0.024	−0.25–0.001
Height	3.9	0.635	< 0.001	2.67–5.15
FVC				
Intervention	0.39	0.14	0.006	0.11–0.66
Age	−0.01	0.006	0.067	−0.25–0.01
Height	4.6	0.70	< 0.001	3.24–5.97
PERF				
Intervention	0.82	0.31	0.008	0.21–1.4
Age	−0.001	0.014	0.98	−0.02–0.02
Height	6.64	1.64	< 0.001	3.42–9.87
Multivariate				
FEV1				
Intervention	0.34	0.11	0.003	0.12–056
Age	−0.006	0.005	0.23	–0.01–0.004
Height	3.66	0.63	< 0.001	2.4–4.9
FVC				
Intervention	0.35	0.13	0.005	0.1–0.59
Age	−0.003	0.006	0.52	−0.015–0.008
Height	4.42	0.70	< 0.001	3.06–5.8
PERF				
Intervention	0.77	0.29	0.009	0.19–1.35
Age	0.012	0.013	.037	−0.014–0.04
Height	6.77	1.66	< 0.001	3.53–10.01

Univariate predictors were incorporated into multivariate models. No significant confounding occurred except that age became a nonsignificant variable in the multivariate model of FEV1.

CI = 95% confidence interval; FEV 1 = forced expiratory volume in 1 second; FVC = forced vital capacity; PEFR = peak expiratory flow rate; SE = standard error.

PEFR was reduced by 44% from baseline in SG *versus* 29% in BG ($P = 0.05$). Again, there were statistically significant differences between the groups for the absolute value of all measures: FEV_1 for SG was 1.41 l *versus* 1.82 l for BG ($P = 0.004$), FVC was 1.66 l for SG *versus* 2.10 l for BG ($P = 0.001$), and PEFR was 3.33 l for SG *versus* 4.26 l in the intervention group ($P = 0.05$).

Two patients, both in BG, required three attempts at intubation; there were no failed intubations. None of the patients enrolled in the study were reintubated in the PACU, unexpectedly admitted to intensive care unit, or required delayed discharge from hospital as a result of a medical complication. There were no deaths or cardiac or respiratory arrests. There were no episodes of hypoxemia ($Spo_2 < 92\%$). There was no statistically significant difference in intraoperative tidal volumes or PEEP. There was no statistically significant difference in intraoperative morphine dosage or postoperative hydromorphone dosage at the time of discharge from PACU and at 24 h postoperatively.

There was no statistically significant difference in heart rate, blood pressure, body temperature, or pulse oximetry values between the groups in the recovery room or day 1 postoperatively. Age, gender, weight (kg), height (cm), body mass index, and apnea hypopnea index did not predict or confound the relationship between group status and vital signs.

Discussion

General anesthesia is associated with significant alterations in pulmonary function and gas handling. Changes in the shape of the chest cavity result in loss of lung volumes, venous admixture, and hypoxemia. Venous admixture is the inevitable consequence of major surgery[18] and general anesthesia, whether or not the patient breathes spontaneously or whether the patient is maintained on volatile or IV anesthetic.[19] Induction of anesthesia causes an immediate significant reduction in FRC of 16 to 20% in the supine position.[20] FRC reaches its final value within the first few minutes of general anesthesia.[21,22] The reduction in FRC is correlated with age and chest wall elastance.[23] It results in airway closure, reduced lung compliance, and ventilation perfusion mismatch. The shape of the chest cavity changes; there is cephalad displacement of the diaphragm.[24] Complete or partial collapse of lung segments is known as atelectasis, which occurs in 90% of anesthetized patients.[25] Up to 20% of lung bases are collapsed soon after induction of anesthesia.[26]

MO patients are widely considered to be at elevated risk for perioperative pulmonary complications secondary to obstructive sleep apnea-hypopnea syndrome and atelectasis.[27] Morbid obesity is associated with dramatically increased chest wall elastance.[27] Vital capacity and FRC decrease after extubation due to residual anesthetic, neuromuscular blockade, and opioids.[28] Spirometry values deteriorate significantly in MO patients undergoing surgery.[29]

Eichenberger *et al.* quantified atelectasis in MO patients *versus* nonobese patients undergoing laparoscopic surgery in the perioperative period. Before induction, the 2.1% of total lung area was atelectatic in the MO *versus* 1.0% ($P < 0.01$) in normal weight patients; after tracheal extubation, atelectasis increased to 7.6% in the MO *versus* 2.8% ($P < 0.05$); and at 24 h, it was 9.7% in MO *versus* 1.9% ($P < 0.01$).[30] An important message from these data is that, unlike in normal weight patients, atelectasis actually worsens in MO patients over the first 24 postoperative hours, often when the patient is less supervised on the ward. Atelectasis and hypoventilation secondary to opioids result in hypercapnia-induced somnolence and may lead to airway obstruction and respiratory arrest.

Loss of FRC, lung derecruitment, airway closure, and airway obstruction predispose patients to hypoxemia.[31] High inspired concentrations of oxygen increases the extent of absorption atelectasis and reduces FRC further.[32] These problems can be offset by the application of CPAP during preoxygenation[11,33,34] intraoperatively[35] and postoperatively.[5–8] In the current study, all subjects received preinduction positive pressure ventilation and postintubation PEEP, spontaneous breathing was avoided under anesthesia, and all subjects received CPAP, as determined preoperatively by a sleep study, for at least 8 h postoperatively. Despite this aggressive approach to prevent atelectasis, patients in SG had on average a 50% reduction in FVC 1 h postoperatively, and this improved little over the course of 24 h. Subjects in BG who had immediate postextubation CPAP showed an average reduction of 27% in FVC.

Several previous studies have investigated postoperative noninvasive ventilation, but none immediately after extubation in the operating room. Ebeo *et al.*[8] evaluated the effect of bilevel positive airway pressure (BiPAP) on pulmonary function in obese patients after open gastric bypass surgery. A total of 27 patients were recruited; 14 received BiPAP, and 13 received conventional postoperative care. FVC and FEV_1 were significantly higher on each of the three consecutive postoperative days in the patients who received BiPAP therapy. The Spo_2 was also significantly increased in the BiPAP group. These improved measures of pulmonary function, however, did not translate into fewer hospital days or a lower complication rate. Our study was similarly underpowered to look for the effect of immediate ventilatory support on relatively uncommon events like reintubation, respiratory arrest, wound infection, and deep venous thrombosis.

Joris *et al.*[4] studied 30 patients who had undergone bariatric surgery. They were assigned to either no noninvasive positive pressure ventilation, low levels of BiPAP (8/4 cm H_2O), or higher levels of BiPAP (12/4 cm

H_2O). Spirometry and oximetry were performed the day before surgery, 24 h after surgery, and on days 2 and 3. The patients receiving the higher BiPAP settings had significantly better spirometry and Spo_2 24 and 48 h after surgery.

Although spirometry is, at best, an indirect measure of lung volume and lung mechanics, previous studies using this technique have consistently demonstrated similarities between the changes in spirometry and degree of atelectasis.[2,4,36] The data from our study seem to be unique in suggesting that there is a significant loss of lung volume in bariatric patients after extubation, and a significant proportion of this can be retained if CPAP is applied immediately. Moreover, this benefit of immediate CPAP is maintained for the first 24 h after extubation, when CPAP is continued through the first postoperative day. This is consistent with studies that showed benefit from intraoperative PEEP, reverse Trendelenburg positioning, and preinduction CPAP.[2,11,14,35–37]

The Boussignac CPAP system is a portable facemask system that can deliver elevated airway pressure using standard oxygen cylinders. When used in PACU as an alternative to noninvasive ventilation, this system significantly improves oxygenation.[9] It has been used widely to improve respiratory symptoms in acute pulmonary edema.[38,39] In this setting, the Boussignac system appears to be as effective as BiPAP.[40]

There are some potential limitations to this study. The majority of patients enrolled in this study were women, reflecting the demographics of bariatric surgery patients.[41] It is possible that different outcomes would have been observed if more men, with characteristic central obesity, were enrolled in this study. All of the patients when placed on BiPAP Vision received CPAP rather than BiPAP, as prescribed by their sleep study. It is possible that postoperative day 1 lung mechanics would have been better if inspiratory pressure support had been used.[4,8] Nevertheless, previous studies that have demonstrated outcome benefits have used CPAP alone.[6,7] Indeed, the poorer outcomes in the low BiPAP group in the study by Joris *et al.* may have resulted from inadequate levels of CPAP.[4] In the current study, the mean CPAP level administered postoperatively in both groups was 10 cm H_2O. The CPAP level administered was determined preoperatively during the patient's sleep study and aimed at minimizing airway obstruction rather than preventing atelectasis. It is unclear whether this was the optimal CPAP level for each of the patients. It is also unclear if these results are generally applicable to bariatric patients; all patients in this study had a known diagnosis of obstructive sleep apnea and were presumably more likely to tolerate positive pressure ventilation delivered by facemask.

Clearly, spirometric values are intermediate outcomes. Our study was not powered nor designed to detect uncommon or rare postoperative outcomes, such as postoperative pneumonia, wound infections, cardiac or respiratory arrest, and death.

Although there were no adverse events in either group, it is important to note that all subjects received highly organized evidence-based care in a high-volume bariatric practice and were managed intraoperatively by a select group of anesthesiologists using a standardized approach (table 1) designed to optimize patient outcome. Despite this, patients in the SG had dramatic deterioration in spirometry values. Therefore, the use of immediate postoperative CPAP most likely represents an additional intervention for risk minimization.

In summary, this was a prospective observer-blinded randomized control trial of immediate postextubation CPAP (using the Boussignac system) *versus* standard care in which CPAP was delayed until arrival in PACU, approximately 30 min after extubation. We have demonstrated that bariatric patients lose significant lung volumes immediately after extubation and that this can be reduced by administration of CPAP at this time. The use of CPAP in the recovery room appears to be too late to restore lost lung volumes.

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