Noninvasive Ventilation Immediately After Extubation Improves Lung Function in Morbidly Obese Patients with Obstructive Sleep Apnea Undergoing Laparoscopic Bariatric Surgery

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BACKGROUND: Noninvasive positive pressure ventilation (NIPPV) may improve postoperative lung function and reduce postoperative complications in patients undergoing abdominal surgery. The purpose of our study was to determine whether the timing of postoperative NIPPV affects lung function 1 day postoperatively.

METHODS: Forty morbidly obese patients with known obstructive sleep apnea undergoing laparoscopic bariatric surgery with standardized anesthesia care were randomly assigned to receive NIPPV immediately after tracheal extubation (immediate group) or supplemental oxygen (standard group). All patients had continuous positive airway pressure initiated 30 minutes after extubation in the postanesthesia care unit (PACU) via identical noninvasive ventilators. Spirometry was performed by a blinded observer in the perioperative holding area 1 hour after admission to the PACU and 1 day postoperatively. The primary outcome was the change in forced vital capacity (FVC) from baseline to 24 hours (FVC baseline–FVC 24 hours).

RESULTS: Forty patients, 20 in each group, were enrolled in the study. Forced expiratory volume in 1 second, FVC, and peak expiratory flow rate were significantly reduced in both groups from perioperative values throughout the study. At 24 hours, the intervention group had lost only 0.7 L FVC, versus 1.3 L for the intervention group (P = 0.0005). An analysis of covariance confirmed this and indicated that the immediate postoperative NIPPV better preserved spirometric function at 1 and 24 hours postoperatively. Specifically, the differences in the primary outcome were statistically significant.

CONCLUSIONS: NIPPV given immediately after extubation significantly improves spirometric lung function at 1 hour and 1 day postoperatively, compared with continuous positive airway pressure started in the PACU, in morbidly obese patients with obstructive sleep apnea undergoing laparoscopic bariatric surgery. (Anesth Analg 2010;110:1360–5)

Patients who are morbidly obese (MO) are at increased risk for perioperative pulmonary complications. These include increased atelectasis due to loss of functional residual capacity (FRC), anesthesia, and surgery, and airway obstruction as a consequence of obstructive sleep apnea (OSA)-hypopnea syndrome, anesthesia, and opioid analgesia.1–4 A variety of intraoperative techniques have been applied to minimize the development of postoperative atelectasis, including reverse Trendelenburg positioning,5–6 recruitment maneuvers,7 intraoperative positive end-expiratory pressure (PEEP),8 and continuous positive airway pressure (CPAP) during induction of anesthesia.9 The period immediately after tracheal extubation is a potentially hazardous time because of the risks of airway obstruction, narcosis, residual anesthesia, and residual neuromuscular blockade.10

Noninvasive positive pressure ventilation (NIPPV) is widely used to reduce the risk of airway obstruction in postoperative bariatric surgery patients with known OSA.11 In our institution, these patients are administered NIPPV in the recovery room within 1 hour of extubation and continued overnight. NIPPV may have a secondary beneficial effect in terms of improving postoperative lung mechanics.10–14 However, the optimal timing of the use of NIPPV remains unclear. We hypothesized that the maintenance of positive airway pressure immediately after extubation and during transit to the postanesthesia care unit (PACU) would result in a significant improvement in lung function, as measured by spirometry, compared with NIPPV commenced in the recovery room. The study population was MO patients with OSA undergoing laparoscopic bariatric surgery.

The objective of this study was to determine whether immediate postoperative NIPPV improves pulmonary function (forced vital capacity [FVC], forced expiratory volume in 1 second [FEV1], and peak expiratory flow rate [PEFR]) in the recovery room and 1 day postoperatively, as measured by spirometry. Spirometric values were evaluated by the reduction in values from baseline to 1 and 24 hours after extubation. The primary outcome measure was
FVC at 24 hours postoperatively. Secondary outcome measures included examining spirometric outcomes at 1 and 24 hours, the number of episodes of hypoxemia (oxygen saturation as measured by pulse oximetry [Spo2] < 92%), reintubation, requirement for naloxone, unplanned admission to intensive care, cardiac or respiratory arrest, and death.

**METHODS**

**Methodology**

After approval from the IRB, all patients gave consent for inclusion in the study. A blinded investigator (GM) recorded all the 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 undergoing gastric bypass surgery, with polysomnography-defined OSA, were randomly assigned to immediate postextubation NIPPV (immediate group [IG]) or NIPPV commencing in the recovery room 30 minutes after extubation (standard group [SG]).

All subjects had the same surgeon. All subjects underwent general anesthesia using a standardized approach based on a pre-existing evidence-based clinical practice guideline (Table 1): pre-induction CPAP/pressure support (7–10 cm H2O/10 cm H2O) positioning in the “ramped position” with the external auditory meatus located at the level of the anterior chest wall; 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 (Fio2 50%), air, desflurane, and vecuronium for maintenance anesthesia; and intraoperative PEEP. Patients with a body mass index (BMI) < 50 received 7 cm H2O PEEP, and patients with a BMI > 50 received 10 cm H2O PEEP.

Intraoperatively, recruitment maneuvers (40 cm H2O for 30–40 seconds) were 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 ketorolac (30 mg) for intraoperative analgesia. All patients were tracheally extubated in the semirecumbent position after complete reversal of neuromuscular blockade. Patients were not permitted to breathe spontaneously under anesthesia.

The SG subjects were extubated to nasal cannulae with 4 to 6 L/min oxygen. They were moved to their bariatric bed in the semirecumbent position and transported to the PACU while receiving oxygen. On arrival to the PACU, the patients were connected to standard monitors, and analgesia was administered via a patient-controlled analgesia device that administered hydromorphone 0.125 mg IV bolus with a 6-minute lockout period. Thirty minutes after extubation, the patients received NIPPV, using a full facemask with pressure settings prescribed from their sleep study. NIPPV was delivered using the same model device (BiPAP Vision®, Respironics, Murrysville, PA) for all subjects.

The IG subjects were extubated and immediately placed on NIPPV via a portable ventilator (Espirit®, Respironics) and a full facemask. All subjects were put on Fio2 of 50% and received inspiratory positive airway pressure (CPAP level from sleep study) and inspiratory positive airway pressure (IPAP) support adjusted to maintain a tidal volume of 400 to 500 mL. These subjects received this ventilatory support during transport to the PACU. On arrival in the PACU, they transitioned onto their planned postoperative noninvasive ventilator (BiPAP Vision) using the settings prescribed from their sleep study. Subsequently, all subjects in both groups received postoperative NIPPV on the first postoperative night for a minimum of 8 hours.

**Measurements**

In the perioperative area, the spirometric process was described and shown to the subjects. A nose clip was placed and a Viasys MicroLab spirometer (Micro Medical, Chatham, Kent, UK) with a MicroGard® microbial filter was used by the bedside to obtain the perioperative spirometric results. Three spirometric attempts were made at each measurement, and the best value was recorded preoperatively, 1 hour postoperatively, and on postoperative day 1. FVC, FEV1, and PEFR were measured and recorded at each time point.

Time 0 was extubation, and the first postoperative measurement occurred 1 hour after extubation. The investigational ventilator was removed from the patient care location before the investigator was called back to perform spirometry 1 hour after extubation. All patients were receiving NIPPV from a BiPAP Vision device at this time. This was discontinued for 5 minutes before spirometry, and the patient was given 4 L of oxygen by nasal cannula (which was discontinued briefly for spirometry). At this point, Spo2 was recorded. At this time (1 hour after extubation), the patients had 3 forced spirometric attempts.
The last recorded heart beat rate and arterial blood pressure readings were noted. The patient was restarted on NIPPV for the duration of the PACU stay. On postoperative day 1, spirometry was repeated 24 hours after extubation using the same methodology, and $\text{SpO}_2$ was again noted.

### Statistical Analysis

Based on previous studies in obese and non-obese populations, a modest effect of the intervention was predicted, with the difference in the mean FVC volumes at 24 hours expected to be 0.3 L, with an SD of 0.3 L. Assuming an $\alpha$ of 0.05 (i.e., significant at $P < 0.05$), 18 patients each in the control and intervention groups would result in a $1 - \beta$ (power) of 82%. Twenty subjects were enrolled in each group to ensure 18 evaluable subjects.

Proportional data were examined by $\chi^2$ analysis or Fisher exact test where cell values are <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. Spirometric values were tested to determine whether they were normally distributed values using the Shapiro-Wilk and Anderson-Darling tests. The primary outcome of change in FVC, between baseline and 24 hours, between the SG and IG, was planned to be examined by a $t$ test (assuming normality of data). Secondary analysis included similar $t$ tests of the spirometric values at 1 and 24 hours. Analysis of covariance (ANCOVA) models were to be developed to determine whether treatment status predicted lung volumes from perioperative to 1 hour and perioperative to 24 hours and whether there were important covariates that affected the relationship examined with the $t$ tests. Significance and fit ($R^2$) were then examined to determine the best model. A priori–identified potential confounders (gender, age, height, BMI, and apnea-hypopnea index) were examined for possible effect of the relation between intervention and spirometric outcome.

All analyses were performed with Stata8 (Stata Corporation, College Station, TX). Power analysis was performed with Power and Precision3 (SPSS, Chicago, IL).

### Randomization

Subjects were stratified based on surgical technique and randomized based on treatment/control into 4 groups using sealed envelopes: 20 patients were randomized to immediate NIPPV, of which 10 underwent laparoscopic gastric banding and 10 underwent hand-assisted laparoscopic roux-en-Y gastric bypass. Twenty patients were randomized to the SG: again, 10 underwent laparoscopic gastric banding and 10 underwent roux-en-Y gastric bypass.

### RESULTS

Forty-three patients were considered for study enrollment. Three patients refused to consent and 40 were randomized, 20 into each strata (surgical type), and within each strata 10 to the SG and 10 to the IG. There were slight differences in baseline variables between the 2 groups (Table 2): the IG was heavier by 18 kg (127.5 vs 145.2 kg) and had a BMI correspondingly larger by 9.4 kg/m$^2$ (45.88 vs 50.49 kg/m$^2$). There were no differences in FEV$_1$ (mean 2.48 vs 2.44; $P = 0.86$), FVC (mean 2.95 vs 2.86; $P = 0.69$), or PEFR (mean 5.88 vs 6.20; $P = 0.5$) between the groups at preoperative measurement (Table 3).

ANOVA models determined that the difference in weight and BMI between the groups did not affect the relationship between intervention and lung volumes at 1 or 24 hours. Furthermore, surgical type also did not affect this relationship. As expected, age and height affected spirometric function. At 1 hour, the best ANCOVA model ($R^2 = 0.59$, $F = 18$, $P < 0.0001$) included intervention ($F = 38$, $P < 0.0001$), age ($F = 13$, $P = 0.001$), and height ($F = 4$, $P = 0.04$). Similarly, at 24 hours, the best model ($R^2 = 0.59$, $F = 17$, $P < 0.0001$) included intervention ($F = 27$, $P < 0.0001$), age ($F = 22$, $P < 0.0001$), and height ($F = 3$, $P = 0.07$). Furthermore, secondary analysis indicated that all patients had a clinically and statistically significant reduction in all spirometric variables 1 and 24 hours after surgery (Table 3). These were shown with $t$ tests, and each relationship was further analyzed with ANCOVA to determine which covariates had an effect on the relationship. There were statistically significant differences between the IG and SG for all postoperative measures: FEV$_1$ in the SG was 1.06 L vs 1.86 L in the IG ($P = 0.001$), FVC in the SG was 1.37 L vs 2.16 L in the IG ($P = 0.001$), and PEFR in the SG was 2.17 L vs 3.94 L in the IG ($P = 0.001$). Age and height were important for FVC, but only age was important for PEFR.

All subjects continued to have a significant reduction in spirometric variables 24 hours after surgery (Table 3), despite a mean CPAP of 9.9 cm H$_2$O (range 2–17 cm H$_2$O) administered postoperatively to the SG and 11.3 cm H$_2$O (range 4–19 cm H$_2$O) to the IG ($P = 0.34$). The SG had a statistically significant improvement in pulmonary mechanics compared with 1 hour postoperatively, whereas the IG had no change in FEV$_1$ and FVC and a mild improvement in PEFR. There were still statistically significant differences between the 2 groups: FEV$_1$ in the SG was 1.34 L vs 1.84 L in the IG ($P = 0.004$), FVC in the SG was 1.64 L

### Table 2. Baseline Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Standard group (SG)</th>
<th>Intervention group (IG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>46.8 (12.36)</td>
<td>46.6 (7.52)</td>
</tr>
<tr>
<td>Sex (F/M)</td>
<td>0.16/4</td>
<td>0.17/3</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>127.52 (20.0)</td>
<td>145.23 (23.4)*</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.67 (0.1)</td>
<td>1.69 (0.1)</td>
</tr>
<tr>
<td>BMI</td>
<td>45.88 (5.14)</td>
<td>50.49 (8.20)*</td>
</tr>
<tr>
<td>Preoperative FEV$_1$</td>
<td>2.48 (0.69)</td>
<td>2.45 (0.59)</td>
</tr>
<tr>
<td>Preoperative FVC</td>
<td>2.95 (0.82)</td>
<td>2.9 (0.69)</td>
</tr>
<tr>
<td>Preoperative PEFR</td>
<td>5.88 (1.68)</td>
<td>6.19 (1.18)</td>
</tr>
</tbody>
</table>

Baseline characteristics: data displayed are mean (so) except for sex, which refers to numbers of female/male.

BMI = body mass index (kg/m$^2$); FEV$_1$ = forced expiratory volume in 1 s; FVC = forced vital capacity; PEFR = peak expiratory flow rate.

* $P = 0.03$. 

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Table 3. Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Standard group (SG)</th>
<th>Intervention group (IG)</th>
<th>P</th>
<th>SG IG</th>
<th>Reduction from preoperative</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1</td>
<td>2.48 (0.49)</td>
<td>2.44 (0.44)</td>
<td>0.86</td>
<td>0.6</td>
<td>0.69</td>
<td>0.001</td>
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<tr>
<td>FVC</td>
<td>2.95 (0.54)</td>
<td>2.86 (0.48)</td>
<td>0.69</td>
<td>0.6</td>
<td>0.5</td>
<td>0.001</td>
</tr>
<tr>
<td>PEFR</td>
<td>5.88 (1.10)</td>
<td>6.2 (0.95)</td>
<td>0.5</td>
<td>0.6</td>
<td>0.001</td>
<td>0.001</td>
</tr>
</tbody>
</table>

1-h postoperative data

<table>
<thead>
<tr>
<th>Test</th>
<th>SG</th>
<th>IG</th>
<th>P</th>
<th>SG IG</th>
<th>Reduction from preoperative</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1</td>
<td>1.06 (0.43)</td>
<td>1.86 (0.56)</td>
<td>0.0001</td>
<td>1.4</td>
<td>0.6</td>
<td>0.0001</td>
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<tr>
<td>FVC</td>
<td>1.37 (.053)</td>
<td>2.16 (0.54)</td>
<td>0.0001</td>
<td>1.6</td>
<td>0.7</td>
<td>0.0001</td>
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<tr>
<td>PEFR</td>
<td>2.17 (1.20)</td>
<td>3.94 (1.30)</td>
<td>0.0001</td>
<td>3.7</td>
<td>2.1</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

1-d postoperative data

<table>
<thead>
<tr>
<th>Test</th>
<th>SG</th>
<th>IG</th>
<th>P</th>
<th>SG IG</th>
<th>Reduction from preoperative</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEV1</td>
<td>1.34 (0.56)</td>
<td>1.84 (0.62)</td>
<td>0.0004</td>
<td>1.1</td>
<td>0.6</td>
<td>0.0001</td>
</tr>
<tr>
<td>FVC</td>
<td>1.64 (.60)</td>
<td>2.2 (.58)</td>
<td>0.0005</td>
<td>1.3</td>
<td>0.7</td>
<td>0.0005</td>
</tr>
<tr>
<td>PEFR</td>
<td>3.30 (1.30)</td>
<td>4.7 (1.6)</td>
<td>0.0016</td>
<td>1.6</td>
<td>1.5</td>
<td>0.0016</td>
</tr>
</tbody>
</table>

Spirometric data are reported as mean (standard deviation). Units for FEV1 and FVC are L and for PEFR are L/min. Reduction from baseline refers to the absolute reduction in spirometry values from the preoperative (baseline) values (preoperative—1 h or 24 h). The intervention group had significantly better spirometry values 1 h postoperatively, and this persisted over the first 24 h. t tests were used.

FEV1 = forced expiratory volume in 1 s; FVC = forced vital capacity; PEFR = peak expiratory flow rate; SG = standard group; IG = intervention group.

High inspired concentrations of oxygen increase the extent of absorption atelectasis and reduce FRC further. These competing problems can be offset by the application of CPAP during oxygen administration, intraoperatively and postoperatively.

In this study, all subjects received preinduction positive pressure ventilation and postintubation PEEP, spontaneous breathing was avoided under anesthesia, and all subjects received CPAP or bilevel positive airway pressure (BiPAP), as determined preoperatively by a sleep study, for at least 8 hours postoperatively. Despite this aggressive approach to prevent atelectasis, patients in the SG had, on average, a 55% reduction in FVC, FEV1, and PEFR 1 hour postoperatively, and this improved little over the course of 24 hours. Subjects in the IG who had immediate postintubation ventilatory support showed an average reduction of 24% in FVC, FEV1, and PEFR.

Several previous studies have investigated postoperative noninvasive ventilation, but none immediately after exubilation in the operating room. Ebeo et al. evaluated the effect of BiPAP on pulmonary function in obese patients after open gastric bypass surgery. Twenty-seven patients were recruited: 14 received BiPAP and 13 received conventional postoperative care. FVC and FEV1 were significantly higher on each of the 3 consecutive postoperative days in the patients who received BiPAP therapy. The Spo2 was also significantly increased in the BiPAP group.

The use of NIPPV as a rescue therapy for postoperative respiratory failure is controversial. Squadrone et al. studied 209 patients who were hypoxemic after major abdominal surgery and randomized them to receive CPAP or standard oxygen therapy. CPAP was associated with a significant reduction in infectious complications and reintubation, and a shorter duration of intensive care unit stay.

The use of NIPPV for postoperative prevention of airway obstruction in patients with OSA is also controversial. There is little published evidence that postoperative CPAP/BiPAP is beneficial in this patient population.

Our study most closely resembles the one by Joris et al., who studied 30 patients who had undergone bariatric surgery. The patients were assigned to no NIPPV, low

vs 2.20 L in the IG (P = 0.000), and PEFR in the SG was 3.30 L vs 4.70 L in the IG (P = 0.001).

None of the patients enrolled in this study proved difficult to tracheally intubate. There was no statistically significant difference in intraoperative tidal volumes or PEEP. There was no statistically significant difference in intraoperative morphine dosage or postoperative hydro-
levels of BiPAP (8/4 cm H2O), or higher levels of BiPAP (12/4 cm H2O). Spirometry and oximetry were performed the day before surgery, 24 hours after surgery, and on days 2 and 3. The patients receiving the higher BiPAP settings had significantly better spirometric and SpO2 values 24 and 48 hours 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.2,10,11 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 noninvasive ventilation is applied immediately. Moreover, this retained volume is maintained for the first 24 hours after extubation with continued CPAP/BiPAP. This possibly reflects a reduction in the quantity of atelectatic lung tissue associated with the continued application of positive airway pressure from the preinduction phase to well into the postoperative period. This is consistent with studies that involved intraoperative PEEP, reverse Trendelenburg positioning, and preinduction CPAP.2,5,6,10,15,18

There are some potential limitations to this study. First, there was a significant difference in weight and BMI between the 2 groups; the IG weighed more (Table 2). However, one would expect that these patients would have worse lung mechanics than the SG, rather than the reverse. ANCOVA analysis indicated that neither weight nor BMI affected the relationship between group and spirometry at any time point. Second, the majority of patients enrolled in this study were female, reflecting the demographics of bariatric surgery patients.39 It is possible that different outcomes would have been observed if more men, with characteristic central obesity, had been enrolled in this study. Finally, one may question whether the same results would have been achieved if a portable nontitratable CPAP system had been used rather than a noninvasive ventilator.

The Respironics Espirit was chosen for this study because, unlike our current noninvasive ventilator, the BiPAP Vision, the device could be run on batteries and oxygen cylinders. We wished to measure and deliver specific levels of BiPAP (8/4 cm H2O), or higher levels of BiPAP to the patient’s sleep study and aimed at minimizing airway obstruction rather than preventing atelectasis. Clearly, spirometric and oximetric values are intermediate outcomes. Our study was not powered to detect uncommon or rare postoperative outcomes. 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, 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 spirometric values. Hence, the use of immediate postoperative NIPPV most likely represents an additional intervention for risk minimization.

In summary, this was a prospective, observer-blinded, randomized, controlled trial of immediate postextubation NIPPV versus standard care in which CPAP was delayed until arrival in the PACU, approximately 30 minutes after extubation. In this study, immediate postextubation NIPPV significantly improved spirometric values and SpO2 1 hour and 1 day after surgery.

AUTHOR CONTRIBUTIONS
PJN was the lead investigator and helped in study design and manuscript preparation. GM helped in data collection. MF helped in equipment preparation and training. NW helped in patient recruitment and consent. EPG helped in patient recruitment and consent and conduct of study. MC helped in study design and data collection. EAO helped in study design, data analysis, and manuscript preparation.

REFERENCES
1. Jones RL, Nzekwu MM. The effects of body mass index on lung volumes. Chest 2006;130:827–33


