RESPIRATORY MEDICINE

The effect of bi-level positive airway pressure on postoperative pulmonary function following gastric surgery for obesity

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Abstract The severely obese patient has varying degrees of intrinsic reduction of expiratory flow rates and lung volumes. Thus, the severely obese patient is predisposed to postoperative atelectasis, ineffective clearing of respiratory secretions, and other pulmonary complications. This study evaluated the effect of bi-level positive airway pressure (BiPAP) on pulmonary function in obese patients following open gastric bypass surgery. Patients with a body mass index (BMI) of at least 40 kg/m^2 who were undergoing elective gastric bypass were eligible to be randomized to receive either BiPAP during the first 24 h postoperatively or conventional postoperative care. Patients with significant cardiovascular and pulmonary diseases were excluded from the study. Forced vital capacity (FVC), forced expiratory volume in 1 s ($FEV_{1.0}$), peak expiratory flow rate (PEFR), and percent hemoglobin oxygen saturation (SpO_2) were measured preoperatively, and on postoperative days 1, 2, and 3. Twenty-seven patients were entered in the study, 14 received BiPAP and 13 received conventional postoperative care. There was no significant difference preoperatively between the study and control groups in regards to age, BMI, FVC, $FEV_{1.0}$. PEFR or SpO_2. Postoperatively, expiratory flow was decreased in both groups. However, the FVC and $FEV_{1.0}$ were significantly higher on each of the three consecutive postoperative days in the patients who received BiPAP therapy. The SpO_2 was significantly decreased in the control group over the same time period. Prophylactic BiPAP during the first 12--24 h postoperatively resulted in significantly higher measures of pulmonary function in severely obese patients who had undergone elective gastric bypass surgery. These improved measures of pulmonary function, however, did not translate into fewer hospital days or a lower complication rate in our study population of otherwise healthy obese patients. Further study is necessary to determine if BiPAP therapy in the first 24 postoperative hours would be of benefit in severely obese patients with comorbid illnesses who have undergone elective gastric bypass.

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Keywords obesity, gastric bypass, pulmonary function tests, percent hemoglobin oxygen saturation.

INTRODUCTION

The function of respiratory muscles and diaphragmatic excursion are impaired in the severely obese (1). There is also restriction of the ability of the chest wall to expand. Thus, vital capacity, total lung capacity, functional residual capacity, forced expiratory volume in 1s ($FEV_{1.0}$), and expiratory reserve volume are all reduced. These parameters are usually normal in those with mild-to-moderate obesity (1,2). The severely obese patients who undergo upper abdominal surgery have greater postoperative risk of developing pulmonary complications due to these limitations of pulmonary function (3,4).

Bi-level positive airway pressure (BiPAP) systems combine pressure support ventilation (PSV) with positive end expiratory pressure (PEEP). The different inspiratory and expiratory positive airway pressures are delivered to the patient via nasal or face mask. BiPAP has been used successfully to treat respiratory failure of various etiologies including obstructive sleep apnea, chronic obstructive lung diseases, and pulmonary edema (5–11). BiPAP may allow for alveolar recruitment during inspiration and prevent expiratory alveolar collapse and may thereby decrease postoperative complications from the pulmonary restrictive syndrome associated with

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obesity (12). This study evaluated the impact of prophylactic use of BiPAP on measures of pulmonary function in severely obese patient following gastric bypass surgery.

MATERIALS AND METHODS

The study was conducted in a suburban community hospital between August 1999 and May 2000. The local Institutional Review Board approved this study. Twenty-seven consecutive patients referred by their primary physicians for gastric bypass surgery were recruited to participate in the study. All of the patients were obese with a body mass index (BMI) of more than 40 kg/m^2. Each patient had failed to lose weight by dietary and medical treatment. All the patients underwent open Roux-enY gastric bypass surgery performed by the same surgeon.

Patients with significant cardiovascular diseases, chronic obstructive lung diseases, obstructive sleep apnea, and obesity hypoventilation syndrome were excluded from the study. Patients who required mechanical ventilation for more than 6 h postoperatively, had complicated surgery, or were unable to tolerate the BiPAP system for at least 12 h were also excluded.

Randomization of the patients to the study or control group was accomplished by selecting the next sequentially numbered sealed envelope that contained a computer-generated assignment. Fourteen patients were assigned to BiPAP group and 13 patients to the conventional treatment group (Fig. 1). The study group received BiPAP (Knightstarr 335, Nellcor Puritan Bennett Inc., 4280 Hacienda Drive, Pleasanton, CA) with an inspiratory positive airway pressure (IPAP) of 12 cmH_2O and an expiratory positive airway pressure (EPAP) of 4 cm H_2O. BiPAP was continued for at least 2 h out of every 3 h during the first 12–24 h postoperatively. The BiPAP machines were set and the nasal masks (Nellcor Puritan Bennett Inc., 4280 Hacienda Drive, Pleasanton, CA) fitted by trained respiratory therapists. During the 1 h rest period the study patients were placed on 5 l/min of oxygen via nasal canula. Oxygen, 5 l/min, was delivered to the control patients by nasal canula immediately after extubation following surgery.

Both groups were monitored for postoperative complications. The study group was also evaluated for facial skin abrasions and breakdown from the nasal mask. The patients' anesthesia induction, general anesthesia, and patient controlled anesthesia were reviewed. The duration of hospital stay and the use of incentive spirometry were also investigated.

Forced vital capacity (FVC), $FEV_{1.0}$, and peak expiratory flow (PEFR) were measured at the same time of day during the first, second, and third postoperative days using the PB-100 portable spirometer (Nellcor Puritan Bennett Inc., 4280 Hacienda Drive, Pleasanton, CA) with the patient in a sitting position. The best of three matched attempts was recorded. Oxygen saturation (SpO_2) at room air was measured using the pulse oximetry (N-3000, Nellcor Puritan Bennett Inc., 4280 Hacienda Drive, Pleasanton, CA) with the patient sitting.

Data were reported as mean $\pm$ SD and analyzed using an unpaired t-test with Welch correction. Pearson chi-square analysis compared the frequency differences between the two groups. Results were considered significant if $P < 0.05$.

RESULTS

Six of the 27 patients enrolled subsequently were withdrawn from the study. Five patients in BiPAP group were removed; four patients were unable to tolerate BiPAP and one had a surgical complication that required prolonged postoperative mechanical ventilation. The main reasons for not completing at least 12 h of postoperative BiPAP therapy were discomfort caused by the positive airway pressure and the nasal appliance and an inability to sleep with the device in place. Out of nine patients remaining in the study group, two patients completed 24 h, two patients completed 16–23 h, and five patients completed 12–15 h of BiPAP therapy. One patient in the control group required prolonged postoperative mechanical ventilation and was omitted from the data analysis (Fig. 1).

Comparison of the study and control patients' demographic characteristics, preoperative pulmonary function tests (FVC, $FEV_{1.0,}$ and PEFR), and preoperative SpO_2 revealed no significant differences between the two groups (Table 1). The parameters of pulmonary function (FVC, $FEV_{1.0,}$ and PEFR) and SpO_2 of both groups deteriorated significantly postoperatively. On postoperative day 1, FVC had decreased to 44% from baseline in control group compared to 55% with BiPAP group (Fig. 2). Similarly, on the first operative day the $FEV_{1.0}$ dropped to 44% from their baseline in control group and to 54% in the BiPAP group (Fig. 3). The FVC and $FEV_{1.0}$ were significantly higher in the study group when compared to the control group ($P < 0.05$). PEFR was higher in the study group than the control group

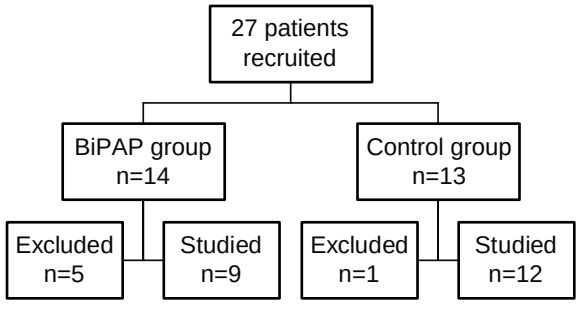

FIG. 1. Patient's randomization.

Table I. Patients' preoperative baseline characteristics

	BIPAP (n=9)	Control (n=12)	P value
Age (year)	37 ± 6	35 ± 10	NS
Sex (M/F)	1/8	0/12	NS
BMI (kg/m^2)	50 ± 7	47 ± 5	NS
Smoking	1/9	1/12	NS
FVC (l)	3.22 ± 0.83	3.39 ± 0.67	NS
FEV_1 (l)	2.73 ± 0.64	2.75 ± 0.66	NS
PEFR (l/s)	5.69 ± 1.61	5.73 ± 1.02	NS
SpO_2 (%)	96.9 ± 0.9	97.8 ± 0.8	NS

Values are mean ± SD. BMI (body mass index), FVC (force vital capacity), FEV_1 (force expiratory volume in 1 s), PEFR (peak expiratory flow rate), SpO_2 (pulse oximetry at room air), NS (not statistically significant).

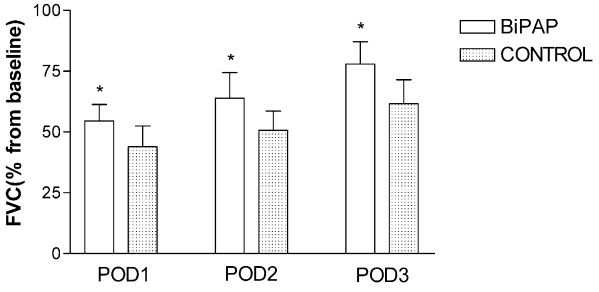

Fig. 2. The measured FVC on postoperative days (POD) 1–3 compared from their baseline preoperative FVC. Values are mean ± SD. *P < 0.05.

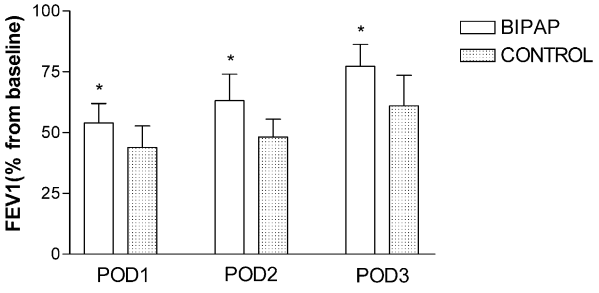

Fig. 3. The measured FEV_1 on postoperative days (POD) 1–3 compared from their baseline preoperative FEV_1. Values are mean ± SD. *P < 0.05.

but did not reach statistical significance (Fig. 4). On postoperative day 1, the mean SpO_2 for the BiPAP and control groups were 97 and 94%, respectively (Fig. 5). These higher levels and statistical significance in FVC, $FEV_{1.0}$, and SpO2 in the BiPAP group were sustained through postoperative days 2 and 3 group (P < 0.05). The PEFR, although maintained at a higher level in the study group, continued to have no statistical difference between the two groups on postoperative days 2 and 3.

Both groups had similar anesthesia, pain control, and incentive spirometry regimens. The duration of hospital

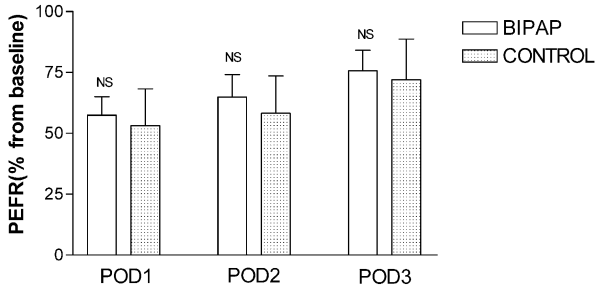

Fig. 4. The measured PEFR on postoperative days (POD) 1–3 compared from their baseline preoperative FVC. Values are mean ± SD. NS (not statistically significant).

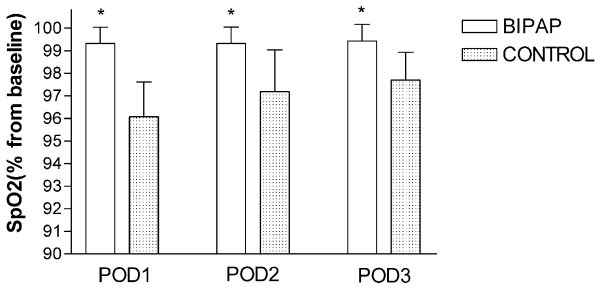

Fig. 5. The measured SpO_2 on postoperative days (POD) 1–3 compared from their baseline preoperative SpO_2. Values are mean ± SD. *P < 0.05.

stay was not significantly different between the two groups of patients (BiPAP, 5.5 ± 1.3 days; control, 5.2 ± 1.8 days). The duration of hospitalization was dictated by the recovery of bowel function and routine postsurgical care. No cardio-pulmonary or other clinical complication such as aspiration or abdominal distention was observed in either group. There were no facial abrasions identified in the study group from to the nasal apparatus. Since the BiPAP therapy was part of an experimental protocol, the precise cost of this intervention could not be determined.

DISCUSSION

The fall in expiratory reserve volume in obesity is due to small-airway closure. Lung compliance is also reduced secondary to low lung volumes and elevation of the hemi-diaphragms especially during recumbency. Thus, the obese patient is predisposed to atelectasis and ineffective clearing of mucus. Work of breathing in the severely obese is increased because of abnormal chest elasticity, increased chest wall resistance, increased airway resistance, abnormal diaphragmatic position, and upper airway resistance (1,2). To help minimize the work of breathing, obese individuals take more frequent but

smaller volume breaths but their ability to increase minute ventilation is limited. Ventilation–perfusion mismatch is common in the severely obese patient especially in the supine position and may cause hypoxemia (2). This hypoxemia may contribute to the increased risk of sudden death observed in the severely obese. Moreover, obese patients dedicate a disproportionately high percentage of total oxygen consumption (V_{O2}) and carbon dioxide production (V_{CO2}) to conduct respiratory work, even during quiet breathing (13). This relative inefficiency suggests a decreased ventilatory reserve and a predisposition to respiratory failure in the setting of even mild pulmonary or systemic insults.

Obesity is a major cause of postoperative complications. Studies have found that after upper abdominal surgery, obesity was one of the most important risk factor associated with clinically significant atelectasis (14). Pulmonary complications were more frequent, were associated with longer hospital stay and occurred in combination with cardiac complications in a substantial proportion of cases (3). The severely obese have mortality rates two or three times as high as normal patients. This is especially true with long vertical upper abdominal incisions (4).

This study demonstrates that the prophylactic use of BiPAP during the first 12–24 h following gastric bypass surgery on severely obese patients significantly raises measures of pulmonary function when these indicators are compared to a control group. A 24–30% increase in FVC and $FEV_{1.0}$ relative to the control group resulted from noninvasive ventilatory support. These improvements were not as substantial when compared to a previous study on a similar population (12). This might be due to the less time spent on the BiPAP system by our patients. The higher levels of FVC, $FEV_{1.0}$, and SpO_2 in the study group were preserved even after discontinuation of the noninvasive ventilation. These data are most likely explained by a decrease in pulmonary microatelectasis and an increased functional residual capacity (FRC) due to the application of positive airway pressure in the first 12–24 h after surgery (15,16). Our data mirror previously reported observations (12).

In agreement with other published data, BiPAP did not result in a significant improvement in PEFR in our patients (12). This finding may in part be explained by the fact that, although the $FEV_{1.0}$ and the PEFR are similar dynamic expiratory maneuvers, the time course and the magnitude of the changes in these two parameters are not identical.

The optimal pressure for IPAP and EPAP following gastric bypass surgery in the severely obese is not known. A previous report suggests that an IPAP of 8 cm H_2O may be inadequate in obese patients to prevent the postoperative pulmonary restrictive syndrome. These authors propose that 12 cm H_2O of IPAP promotes lung inflation and 4 cm H_2O of EPAP prevents end-expiratory alveolar collapse (12). These settings were well tolerated and there was no increase in complication in their patients treated with these pressures. While our study was not designed to investigate the optimal level of BiPAP, our data confirm their observations that an IPAP of 12 cm H_2O and an EPAP of 4 cm H_2O result in higher postoperative measures of pulmonary function. The optimal IPAP and EPAP, however, for any given patient are difficult to predict and will require more research before the clinician will be able to reliably forecast what pressures to use.

Our patients did not tolerate BiPAP as well as previously reported accounts of postoperative BiPAP in severely obese patients undergoing gastric bypass surgery (12). Twenty-nine percent of our patients enrolled in the study group withdrew due to an inability to tolerate this treatment for at least 12 h. This is more than the intolerance to this treatment reported previously in 13% of patients (12). The reason for this difference is not clear but is probably due to a number of factors including patient education and expectations of BiPAP. Patient tolerance of BiPAP and the nasal apparatus may be improved by a preoperative education and a trial of BIPAP before surgery.

Whether or not the observed effects of postoperative BiPAP on pulmonary function following gastric bypass surgery are clinically relevant remains to be answered. While there were significant differences in the FVC, $FEV_{1.0}$, and SpO_2 between our patients who did and did not receive BiPAP, the duration of hospital stay for each group was the same. The hospital stay, however, was mainly dependent on the recovery of gastrointestinal motility rather than pulmonary function. No cardio-pulmonary or other complication was observed in either group. This is may be due to the relative health of the patients that were enrolled in our study. Whether inclusion of a larger number of patients into this study would eventually result in clinically significant findings in patient outcome is debatable. The exact cost of BiPAP therapy was not determined. However, due to the greater intensity of postoperative care provided by respiratory care personnel, a higher cost of hospitalization would be expected if this intervention was routinely employed following gastric bypass surgery in the severely obese.

The limitations of our study were the number of subjects and the exclusions of patients with cardio-pulmonary and other comorbid illnesses who might clinically benefit from postoperative BiPAP. Nevertheless, our study demonstrates that the prophylactic use of BiPAP with an IPAP of 12 cm H_2O and EPAP of 4 cm H_2O during the first 12–24 h following gastric bypass surgery significantly improved measures of pulmonary functions in otherwise-healthy but severely obese patients. Since BiPAP therapy has been employed effectively to treat pulmonary insufficiency due to a variety of disease processes, then patients with underlying comorbid

illnesses who are undergoing gastric bypass surgery may be the population that benefits most from this therapy. The improvement in pulmonary function from prophylactic BiPAP observed in this study of otherwise-healthy obese patients suggests that further research should be performed to determine what advantage this intervention may have for the severely obese patients with underlying comorbid conditions that are undergoing bariatric surgery.

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