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SCIENTIFIC INVESTIGATIONS

Outcomes Associated with Early Postoperative Noninvasive Ventilation in Bariatric Surgical Patients with Sleep Apnea

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Study Objectives: To examine the relationship of early initiation of noninvasive ventilation (NIV) with postoperative outcomes in patients with obstructive sleep apnea (OSA) undergoing bariatric surgery.

Methods: We included 5,266 patients with OSA undergoing bariatric surgeries at 161 hospitals in the United States. We defined early postoperative NIV as NIV used on the day of or the day after surgery; this could include prophylactic NIV or NIV used for early signs of respiratory deterioration. We developed a hierarchical model to identify factors associated with early use of NIV. Then, in a propensity matched cohort, we assessed the association between NIV use and outcomes.

Results: Overall, 996 patients (18.9%) were treated with early postoperative NIV. Predictors of NIV initiation were: male sex (odds ratio: 1.34, 95% confidence interval 1.14–1.59), older age, chronic obstructive pulmonary disease (COPD; odds ratio 1.39, confidence interval: 1.17–1.64), gastric bypass surgery, short-acting narcotics intravenous on the day of surgery and admission to a hospital with high rate of OSA diagnosis. In a propensity matched analysis, we found no significant association between early initiation of NIV and receipt of invasive mechanical ventilation (IMV) (early NIV 4.5% vs. no NIV 3.8% p = 0.46), cardiovascular complications or mortality. Results were consistent in several sensitivity analyses.

Conclusions: In this large observational study of patients with OSA undergoing bariatric surgery, early postoperative NIV use was not associated with better outcomes including less intubation and mortality. Properly designed controlled trials will be necessary to provide more definitive answers to this important clinical question.

Keywords: continuous positive pressure ventilation, general surgery, outcome research, sleep disorders

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INTRODUCTION

Obstructive sleep apnea (OSA) is an increasingly recognized chronic condition that is an independent risk factor for a broad set of cardiovascular and metabolic disorders. The exact prevalence of OSA is unknown, with estimates ranging from 9% to 24% in the general population.[1–4] Patients undergoing surgical procedures are more likely to have OSA than the general population, and a recent study reported an overall prevalence of 22% OSA in adult patients undergoing elective surgeries.[5] Numerous observational studies have found that compared to patients without OSA, patients with OSA have a higher risk of postoperative complications, including respiratory failure, intubation, cardiac events and transfers to the intensive care unit.[6–8]

First-line therapy for OSA involves the nighttime application of noninvasive positive pressure devices, continuous positive pressure (CPAP), or bilevel pressure support (BIPAP); but patient adherence to noninvasive ventilation (NIV) remains problematic.[9,10] The American Society of Anesthesiologists recommends routine postoperative use of NIV in patients with OSA who were using it preoperatively, and early initiation of NIV among patients in whom evidence of airway obstruction or hypoxemia develops in the postoperative period.[11,12] These recommendations are largely based on expert opinions, and evidence on whether prophylactic postoperative NIV improves outcomes in patients with OSA is weak.[10,13–15] A recent

BRIEF SUMMARY

Current Knowledge/Study Rationale: Several professional societies including the American Society of Anesthesiology recommend routine postoperative use of noninvasive ventilation (NIV) in patients with OSA who were using it preoperatively and early initiation of NIV for postoperative hypoxemia. However evidence on whether prophylactic postoperative NIV improves outcomes in patients with OSA is weak.

Study Impact: In this large observational study, we found that one in five patients with OSA undergoing bariatric surgery received early NIV, and the rates of NIV use varied largely across the hospitals. Although we could not make a clear distinction between prophylactic use of NIV and early treatment of respiratory deterioration, our results suggest that early use of NIV was not associated with better outcomes, including intubation and mortality rates.

meta-analysis of 6 studies and 904 patients suggested that there was no significant difference in the postoperative adverse events, between CPAP users and nonusers, when CPAP was used acutely in the postoperative period.[16]

Obesity is a well-recognized risk factor for OSA,[17] and estimates of the prevalence of OSA among patients undergoing weight-loss surgery range from 27% to 70%.[18–20] Consequently, the American Society of Metabolic and Bariatric Surgery's position statement on OSA supports consideration of testing all patients who have undergone bariatric surgery; and therefore, most bariatric care programs in North America conduct some form of screening for sleep disorders.[21,22] Although CPAP is increasingly used as a prophylactic strategy, two small single center studies have found no benefit and there has been no larger trials or observational studies to support it.[23,24] Given the relative scarcity of research in this area, using data from a large consortium of US hospitals, we aimed to (1) assess patient and hospital factors, associated with early initiation of NIV, in the postoperative period and (2) examine the relationship of early NIV use with postoperative outcomes, in patients with OSA undergoing bariatric surgery.

METHODS

Design and Setting

We conducted a retrospective cohort study using a voluntary, fee-supported database (Premier Healthcare Informatics, Charlotte NC) that contains highly detailed records from a geographically and structurally diverse sample of approximately 400 hospitals located throughout the United States. In addition to the elements found in standard hospital claims (e.g. UB-04), the database also contains an itemized, date-stamped log of every item billed to the patient or insurer, including medications, laboratory tests, and diagnostic and therapeutic services. The dataset has been extensively used for research, and an in-depth description has been published previously.[25,26]

Patient Population

We included patients, aged 18 years and older, undergoing a bariatric surgery (International Classification of Diseases (ICD) version 9, ICD-9 procedure code: 43.89, 44.38, 44.39, 44.31, 44.68, 44.95–97, 45.91, 50.11, 85.32, 86.83) between January 1, 2007 and June 30, 2011. We restricted the cohort to patients with a diagnosis of OSA (ICD-9-CM diagnostic code: 327.23, 327.20, 780.57, 780.51, 780.53, 327.21, 786.04, 327.27, 327.26).

We excluded patients transferred from another facility, as we could not determine the treatments received prior to transfer. We also excluded patients with bariatric procedures other than laparoscopic, open bypass, or restrictive surgeries, because the nature of the surgery was not well defined, and patients with surgery performed after day 1 of hospitalization, because it is unlikely for an elective surgery to be scheduled later during hospitalization. Because our exposure was defined as NIV delivered on the day of or the day after surgery, we excluded patients who remained intubated after surgery, defined as patients with a billing or procedure code for invasive mechanical ventilation (IMV) on the day of and day after surgery, but without a procedure code for intubation (96.04 insertion of endotracheal tube). We excluded cases where IMV and NIV were recorded on the same day, and were delivered for only 1 day, because we were unable to determine the sequence of ventilation (**Figure 1**).

Patient and Hospital Characteristics

Demographic characteristics of the patients, primary insurance, type of bariatric surgery (laparoscopic bypass, open bypass, restrictive procedure) and type of anesthesia (general, with or without neuraxial) were recorded. The prevalence of individual comorbidities were assessed using AHRQ Healthcare Cost and Utilization software,[27] and also summarized using a validated comorbidity score.[28] We evaluated the dose of the opioid, in morphine equivalents, on the day of surgery along with the mode of delivery (intravenous, oral) and the dose of benzodiazepines and other medications used for pain management[29] (**Appendix A** in the supplemental material).

For each hospital, we recorded the proportion of bariatric patients with an OSA diagnosis, (hospitals may have different awareness of the importance of OSA as a risk factor for postoperative complications, which may influence both documentation and management) along with the proportion of OSA patients treated with postoperative NIV among bariatric patients and among all surgical patients. Other hospital characteristics were also recorded, including the number of beds, teaching status, geographic region, and whether an urban/rural population is served.

Exposure Variable

Early postoperative NIV was the main exposure variable, and was identified based on date stamped billing/charge codes and/or ICD-9 procedure code 93.90. Identification of NIV use based on a charge or an ICD-9 procedure codes for NIV was shown in prior studies to be more sensitive and specific than either alone. Of note, neither procedure nor billing codes differentiate between CPAP and BIPAP.

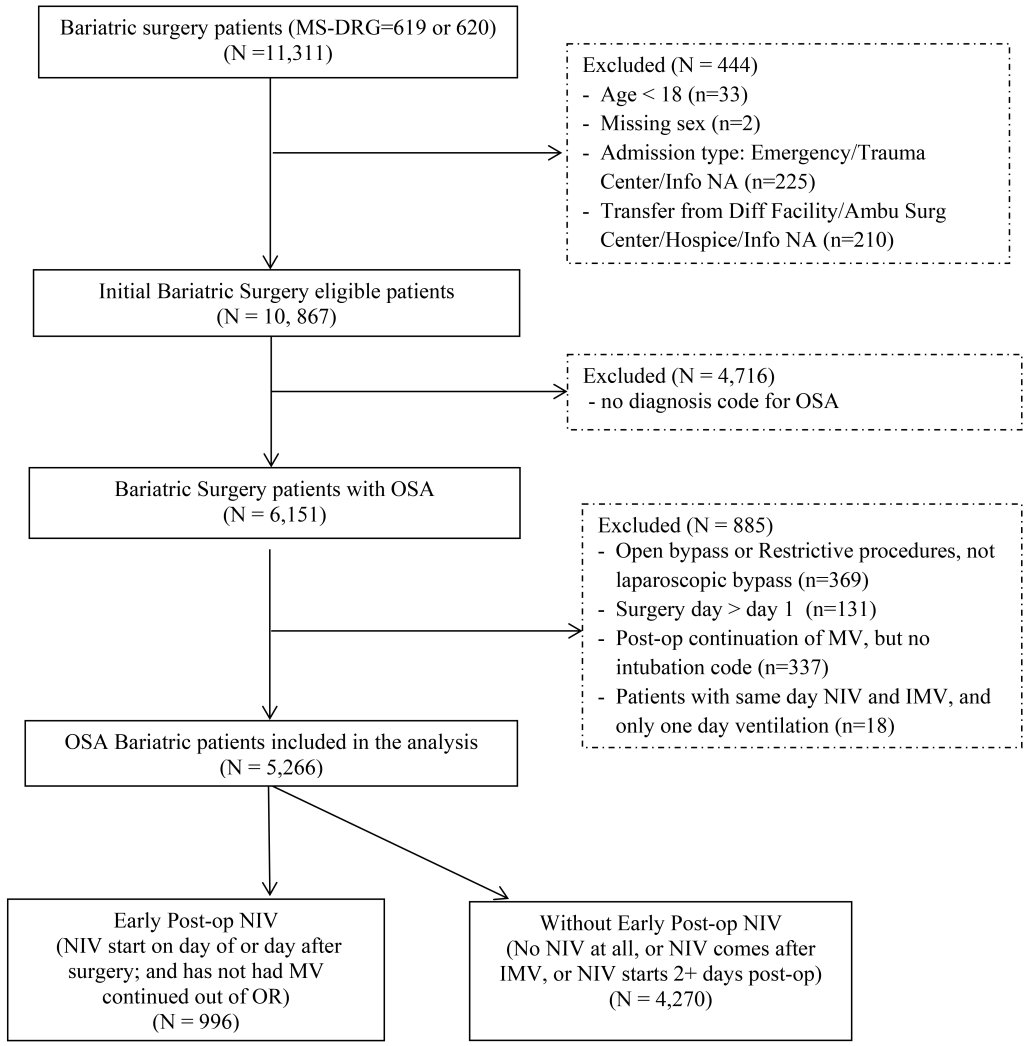
We defined "early postoperative NIV" as NIV started on the day of, or the day after surgery (day 1 or 2 of hospitalization) to acknowledge that we could not differentiate between NIV used for prophylaxis (continuation of NIV used preoperatively) and NIV used to treat early signs of respiratory deterioration in the postoperative period (identified based on chest x-ray [CXR] and arterial blood gas [ABG] orders).

Main Outcomes Measures

The primary outcome of the study was reintubation within 3 days after the surgical procedure and was defined based on the respiratory therapist billing code for IMV and ICD-9 procedure codes for intubation and/or mechanical ventilation (ICD-9: 96.04, 96.7x).[30]

Secondary outcomes were postoperative complications, including acute coronary syndrome, atrial and ventricular arrhythmias, acute congestive heart failure, cardiac arrest, prolonged IMV and delirium. (for ICD-9 codes see **Appendix B** in the supplemental material) In addition, we assessed administration of naloxone on day 1 or 2 after surgery, a short-acting

Figure 1—Study flow chart.



opioid antagonist as a proxy for respiratory depression assumed to be secondary to opioid administration. We also reported in-hospital mortality, length of stay, and hospital cost. All postoperative complications described were not present on admission (no present on admission indicator).[31]

Statistical Analysis

Frequencies and percentages for categorical factors, and medians and interquartile ranges (IQRs) for continuous factors were used to examine the distribution of variables, at the patient and hospital level, and to describe the study population. The univariate associations of patient characteristics, type of surgery and hospital characteristics with early postoperative use of NIV were evaluated via chi-square tests, analysis of variance, or nonparametric Kruskal-Wallis tests.

To assess the association of early postoperative use of NIV with the outcomes of interest, we first developed a nonparsimonious hierarchical logistic regression model to estimate a patient's propensity for early postoperative use of NIV. Because we did not have information regarding the severity of OSA or preoperative presence of hypercarbia, we adjusted for factors associated with OSA severity including age, male sex, morbid obesity, diabetes mellitus, presence of COPD, pulmonary hypertension, and several other patient and hospital factors. Independent variables included patient demographics and comorbidities, medications used for pain management, type of surgery and anesthesia, hospital characteristics, and selected interaction terms. Using a Greedy Match algorithm, we matched each patient treated with early postoperative NIV to another who was not treated with early NIV, but had a similar propensity score. We used conditional logistic regression, to account for matching, in evaluating the effect of early postoperative NIV on reintubation. We also developed a series of hierarchical models, including a hospital random effect, adjusting for propensity for treatment, and other covariates to assess the effect of early NIV on the outcomes. Logit link functions were used for the outcomes of reintubation and other postoperative complications, whereas the identity link was used for log transformed cost and length of stay.

We estimated both the average treatment effect, and the average effect of treatment in the treated. Therefore, in additional models, we used the propensity score to calculate stabilized

inverse-probability of treatment weights, which estimates treatment effects in a population with a risk factor distribution similar to the full study population (average treatment effect), and standardized mortality ratio (SMR) weighting, which estimates the effect in a population with risk factors distribution similar to those treated with NIV (average effect of treatment in the treated).[32–35]

Sensitivity Analysis

We carried out two sensitivity analyses to improve the validity of our findings. First, to increase the likelihood that NIV was used for prophylaxis rather than as a rescue therapy for respiratory distress, we restricted the definition of early postoperative NIV to patients *who did not undergo* an ABG and/or CXR on the day of surgery. We hypothesized that these tests were more likely to be ordered in patients with new onset of respiratory symptoms, and in this case NIV was most likely used for a therapeutic purpose rather than for prophylaxis. Because the aforementioned restriction necessarily excluded patients from the early NIV group who deteriorated while on NIV, in another sensitivity analysis we excluded patients with an ABG or CXR on the day of surgery from both groups (with or without early NIV).

Finally, we compared the outcomes of patients who did not receive NIV at any time during hospitalization, patients who received early NIV, and patients who received late NIV (on or after day 3).

All analyses were carried out using the Statistical Analysis System (version 9.3, SAS Institute, Inc. Cary, NC). The Institutional Review Board at Baystate Medical Center approved the study.

RESULTS

Among the 10,867 bariatric surgery patients eligible for the study, 6,151 patients (56.6%) had an ICD-9 diagnosis of OSA or related sleep disorder. After applying additional exclusion criteria, 5,266 patients were included in the analysis and of these, 996 (18.9%) received early postoperative NIV (**Figure 1**).

Median age of the patients was 50 y (IQR: 41, 57), 68.9% were female, and 69.6% were white. Laparoscopic gastric bypass (63.2%) was the most frequently used surgical procedure. The most common comorbidities were hypertension (71.7%), diabetes mellitus (49.1%), depression/psychoses (36.7%) and chronic pulmonary disease (28.9%) (**Table 1**). Among all patients, 3.8% received IMV within 3 days postsurgery, 1.0% had prolonged IMV, 10.2% had postoperative atrial or ventricular arrhythmia not present at admission, 3.4% received naloxone, and 0.3% died during hospitalization (**Table 2**).

Across the 161 hospitals, the median rate of OSA diagnosis among bariatric surgery patients was 50.0% (IQR, 40.0–64.0%), and the median rate *of early NIV* use among OSA bariatric surgery patients was 8.6% and ranged from 0.6% at the 10th percentile to 66.7% at the 90th percentile. NIV was started on the day of the surgery in 71.8% of the cases treated with early NIV.

When compared to patients who did not receive early NIV, those patients who were treated with early NIV were slightly older, more likely to have chronic pulmonary disease (34.2% vs. 27.7%), received a higher dose of narcotics on the day of surgery, had an ABG or a CXR on the day of NIV initiation (47% vs. 30%), and received naloxone (6.7% vs. 2.7%). Patients who received early NIV were also more likely to be admitted to hospitals with higher rates of OSA diagnosis among bariatric patients, higher rates of NIV use among bariatric patients, and higher rates of NIV use among all surgical patients with OSA (**Table 1**).

The incidence of IMV initiation within 3 days (4.3% vs. 3.7%, $p = 0.34$), prolonged ventilation, cardiac events, and mortality were not significantly different between the patients who received and those who did not receive early NIV. Length of stay and costs were higher in patients treated with early NIV (**Table 2**).

Predictors for Early Postoperative NIV Use

In a hierarchical model that included patient characteristics (sociodemographic, comorbidities, medications), type of bariatric surgery, and hospital characteristics, we found that older age, male sex (odds ratio [OR], 1.34 [confidence interval (CI), 1.14–1.59]), nonrestrictive bariatric surgery, coexistence of chronic lung disease (OR, 1.39 [CI, 1.17–1.64]), neurological disorder (OR, 1.49 [CI, 1.05–2.11]), intravenous use of short-acting narcotics on the day of surgery (OR, 1.50 [CI, 1.00–2.26]) as well as admission to a hospital with a higher rate of OSA diagnosis among bariatric surgery patients were predictors for the receipt of NIV in the first 2 days of hospitalization (**Table 3**).

Results of Propensity Adjusted and Propensity Matched Analysis

The propensity model had a c-statistic of 0.82, and 815 patients (82%) treated with early NIV were matched with patients of similar propensity who were not treated with NIV. The majority of the covariates were equally distributed between the two groups (**Table S1** in the supplemental material). In the matched cohort, differences in rates of intubation (4.5% IMV among NIV-treated vs. 3.8% IMV among untreated, OR: 1.20 95% CI: 0.74–1.95), prolonged ventilation, arrhythmias, mortality, and length of stay between the NIV treated versus not NIV treated were nonsignificant. The use of naloxone (6.6% vs. 3.6%, $p = 0.005$) and the median cost of hospitalization ($14,837 vs. $13,415, $p < 0.001$) remained significantly higher among NIV-treated patients in the matched cohort (**Table 4**). In a conditional logistic regression model, in the matched sample, there was no association between the use of early NIV and initiation of IMV within 3 days postsurgery (OR = 1.20, 95% CI: 0.74–1.95).

In a full cohort model, adjusted for covariates and propensity score, results were similar to the matched analysis, indicating an elevated but not significant risk of intubation for early treatment of patients receiving NIV. SMR weighting gave similar results to the matched analysis (**Figure 2**).

Sensitivity Analysis with Early NIV Definition Restriction

In the first sensitivity analysis, in which we restricted the definition of early prophylactic NIV to patients who did not undergo ABG or CXR on the day of surgery, the incidence of IMV within 3 days (3.9% vs. 4.8%, $p = 0.45$) was lower among

Table 1—Characteristics of bariatric surgery patients with OSA (with and without early postoperative noninvasive ventilation).

	Overall (n = 5,266)	Early Postoperative NIV (n = 996)	No Early Postoperative NIV (n = 4,270)	p
Patient Characteristics				
Sex, female, n (%)	3,631 (69.0%)	647 (65.0%)	2,984 (69.9%)	0.002
Age, median (Q1, Q3)	50 (41, 57)	51 (43,58)	49 (41, 57)	< 0.001
Race, n (%)				0.04
White	3,668 (69.7%)	689 (69.2%)	2,979 (69.8%)	
Black	686 (13.0%)	117 (11.7%)	569 (13.3%)	
Hispanic	152 (2.9%)	22 (2.21%)	130 (3.0%)	
Comorbidities, n (%)				
Hypertension	3,775 (71.7%)	754 (75.7%)	3,021 (70.7%)	0.002
Diabetes	2,584 (49.1%)	512 (51.4%)	2,072 (48.5%)	0.10
Depression/psychoses	1,933 (36.7%)	355 (35.6%)	1,578 (37.0%)	0.44
Chronic pulmonary disease	1,523 (28.9%)	341 (34.2%)	1,182 (27.7%)	< 0.001
Liver disease	833 (15.8%)	132 (13.3%)	701 (16.4%)	0.01
Hypothyroidism	785 (14.9%)	143 (14.4%)	642 (15.0%)	0.59
Deficiency anemias	515 (9.8%)	113 (11.3%)	402 (9.4%)	0.06
Congestive heart failure	330 (6.3%)	69 (6.9%)	261 (6.1%)	0.34
Renal failure	282 (5.4%)	68 (6.8%)	214 (5.0%)	0.02
Neurological disorders	229 (4.4%)	56 (5.6%)	173 (4.1%)	0.03
Combined comorbidity score, median (Q1,Q3)	0 (0,1)	0 (0,1)	0 (0,1)	0.003
ABG or CXR on day 1 or 2, n (%)	1,742 (33.1%)	471 (47.3%)	1,271 (29.8%)	< 0.001
Medications on day of surgery, n(%)				
IV narcotics short-acting	4,706 (89.4%)	893 (89.7%)	3,813 (89.3%)	0.74
Oral acetaminophen	492 (9.3%)	69 (6.9%)	423 (9.9%)	0.004
Oral gabapentin	224 (4.3%)	56 (5.6%)	168 (3.9%)	0.02
Benzo short-acting	4,099 (77.8%)	752 (75.5%)	3,347 (78.4%)	0.05
Total benzo on day of surgery	4 (4, 8)	4 (4, 8)	4 (4, 8)	0.51
Medication on day after surgery, n (%)				
Total narcotic	26.7 (8.0, 49.8)	26.7 (10, 60)	25 (7.5, 42)	< 0.001
Total benzo	4 (2, 8)	4 (2.5, 8)	4 (2, 8)	0.45
Bariatric surgery type, n (%)				0.86
Restrictive	1,126 (21.4%)	209 (21.0%)	917 (21.5%)	
Laparoscopic bypass	3,326 (63.2%)	628 (63.1%)	2,698 (63.2%)	
Open bypass	814 (15.5%)	159 (16.0%)	655 (15.3%)	
Hospital Characteristics				
Urban, n (%)	5,049 (95.9%)	950 (95.4%)	4,099 (96.0%)	0.38
Teaching, n (%)	2,573 (48.9%)	516 (51.8%)	2,057 (48.2%)	0.04
Bed size, n (%)				< 0.001
Small (< 200)	361 (6.9%)	46 (4.6%)	315 (7.4%)	
Medium (200–399)	2,152 (40.9%)	458 (46.0%)	1,694 (39.7%)	
Large (≥ 400)	2,753 (52.3%)	492 (49.4%)	2,261 (53.0%)	
Provider area, n (%)				< 0.001
Midwest	1,893 (36.0%)	403 (40.5%)	1,490 (34.9%)	
Northeast	1,009 (19.2%)	255 (25.6%)	754 (17.7%)	
South	1,816 (34.5%)	237 (23.8%)	1,579 (37.0%)	
West	548 (10.4%)	101 (10.1%)	447 (10.5%)	
OSA rate for bariatric patients, median (IQR)	0.58 (0.48,0.68)	0.60 (0.48, 0.75)	0.56 (0.48, 0.67)	< 0.001
Hospital NIV rate, median (IQR)				
Bariatric OSA patients	0.154 (0.06,0.27)	0.30 (0.19, 0.55)	0.10 (0.04, 0.20)	< 0.001
All surgical patients (Day 1, 2)	0.012 (0.007,0.02)	0.02 (0.01, 0.04)	0.01 (0.007, 0.02)	< 0.001
Surgical OSA patients (Day 1, 2)	0.095 (0.06,0.185)	0.2 (0.118,0.39)	0.092 (0.05,0.138)	< 0.001

ABG, arterial blood gas; Benzo, benzodiazepine; CXR, chest x-ray; IQR, interquartile range; NIV, noninvasive ventilation; OSA, obstructive sleep apnea.

those treated with NIV, but not significantly different among the propensity matched groups (**Figure 3** and **Table 5**).

In a second sensitivity analysis, that excluded all patients with ABG or CXR on the day of surgery, we found that in the

Table 2—Unadjusted outcomes of patients with and without early postoperative noninvasive ventilation.

	Overall (n = 5,266)	Early Postoperative NIV (n = 996)	No Early Postoperative NIV (n = 4,270)	p
MV within 3 days postsurgery, n (%)	200 (3.8%)	43 (4.3%)	157 (3.7%)	0.34
IMV prolonged, n (%)	51 (1.0%)	10 (1.0%)	41 (1.0%)	0.90
Acute coronary syndrome/myocardial Infarction, n (%)	25 (0.5%)	6 (0.6%)	19 (0.4%)	0.45
Atrial and ventricular arrhythmias, n (%)	535 (10.2%)	123 (12.3%)	412 (9.7%)	0.01
Atrial fibrillation/flutter, n (%)	109 (2.1%)	25 (2.5%)	84 (2.0%)	0.28
Exacerbations of heart failure, n (%)	89 (1.7%)	21 (2.1%)	68 (1.6%)	0.26
Cardiac arrest, n (%)	25 (0.5%)	5 (0.5%)	20 (0.5%)	0.80
Delirium, n (%)	6 (0.1%)	2 (0.2%)	4 (0.1%)	0.32
Naloxone, n (%)	180 (3.4%)	66 (6.6%)	114 (2.7%)	< 0.001
Mortality, n (%)	16 (0.3%)	3 (0.3%)	13 (0.3%)	> 0.99
Patient cost, median (Q1, Q3)	13184 (10070, 18240)	14814 (11088, 19297)	12801 (9883, 17943)	< 0.001
Length of stay, median (Q1, Q3)	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	< 0.001

IMV, invasive mechanical ventilation; MV, mechanical ventilation; NIV, noninvasive ventilation.

Table 3—Predictors of early postoperative noninvasive ventilation use.

Effect	OR (95% CI)
Male sex	1.343 (1.135, 1.589)
Chronic lung disease	1.386 (1.169, 1.642)
Valvular disease	1.817 (1.173, 2.814)
Other neurological disorders	1.487 (1.047, 2.112)
IV narcotics short acting	1.504 (1.002, 2.257)
Age group, y	
18–34	0.463 (0.314, 0.683)
35–44	0.608 (0.438, 0.844)
45–54	0.817 (0.600, 1.112)
55–64	0.820 (0.599, 1.122)
65+	Referent
Bariatric surgery type	
Restrictive	Referent
Laparoscopic Bypass	1.440 (1.161, 1.787)
Open Bypass	1.529 (1.137, 2.056)

CI, confidence interval; IV, intravenous; OR, odds ratio.

propensity matched cohort, the intubation rate was higher in the early NIV group (4.0% vs. 3.0% p = 0.38) but not significantly different (**Table S2** in the supplemental material).

In the analysis that compared no NIV, early NIV, and late NIV, we found that patients who received NIV on or after day 3 of hospitalization had significantly increased risk for intubation and longer length of stay than the group who received early NIV and the group who received no NIV but mortality was not significantly different (IMV at any time: 3.5%, 6.1% and 23.7%, p < 0.001; mortality:0.3%, 0.3%, and 1.1%, p = 0.14).

DISCUSSION

In this large observational study of more than 5,000 patients, with a diagnosis of OSA, undergoing bariatric surgery at 161 US hospitals, we found that one in five patients received NIV on the day of or the day after surgery. Early use of NIV was not associated with better or worse outcomes, including intubation, mortality rates, and hospital lengths of stay and costs were slightly higher. This lack of association persisted in two sensitivity analyses that excluded patients with laboratory tests, indicating concern for possible early respiratory deterioration. Patients who received late NIV had higher risk of intubation and longer hospital stay, but mortality was not increased compared with patients treated with early NIV. Although these findings may reflect a lack of effectiveness of early use of NIV to prevent postoperative adverse outcomes, our results suggest that at least some of the NIV administered to patients in the early postoperative period was intended to treat respiratory distress, rather than for prophylaxis.

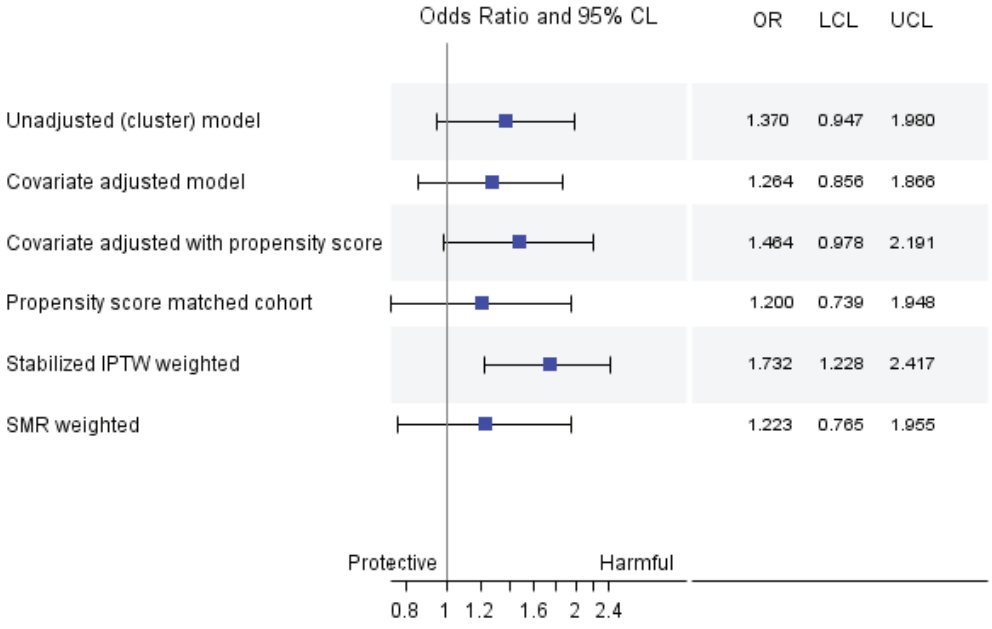
In recent years, several studies and meta-analyses have shown that OSA is associated with increased risk of postoperative cardiopulmonary complications and longer hospital stay, although somewhat unexpectedly not with increased in-hospital mortality.[7,36] As a result, the American Society of Anesthesia has issued guidelines for management of patients with OSA in the perioperative period, including provision for CPAP postoperatively. As a result, hospitals felt obligated to implement processes of care, such as initiating prophylaxis with CPAP in patients with OSA or at high risk of OSA, with the goal of decreasing the risk of complications. However, clinical trials of prophylactic postoperative NIV have shown mixed results. For example, a recent meta-analysis that included six trials did not show any difference in the rate of postoperative adverse events between CPAP and no-CPAP therapy.[16] Two single-center retrospective cohort studies, one of patients undergoing Roux-en-Y bypass and the other of patients undergoing gastric banding surgeries, did not show any benefit of prophylactic NIV.[23,24] Our study extends this prior work, through the use of a multihospital database that provides a larger sample size and detailed coding and billing data, including medications. In addition, we performed two sensitivity analyses aiming to restrict the cohort to patients who did not have laboratory testing suggestive of respiratory

Table 4—Outcomes in propensity matched sample (815 of 996, 82% are matched) for full cohort.

	Overall (n = 1,630)	Early Postoperative NIV (n = 815)	No Early Postoperative NIV (n = 815)	p
IMV within 3 days, n (%)	68 (4.2%)	37 (4.5%)	31 (3.8%)	0.46
IMV prolonged, n (%)	24 (1.5%)	9 (1.1%)	15 (1.8%)	0.22
Acute coronary syndrome/myocardial infarction, n (%)	10 (0.6%)	4 (0.5%)	6 (0.7%)	0.53
Atrial and ventricular arrhythmias, n (%)	186 (11.4%)	101 (12.4%)	85 (10.4%)	0.21
Atrial fibrillation/flutter, n (%)	42 (2.6%)	22 (2.7%)	20 (2.5%)	0.75
Exacerbations of heart failure, n (%)	38 (2.3%)	18 (2.2%)	20 (2.5%)	0.74
Cardiac arrest, n (%)	8 (0.5%)	4 (0.5%)	4 (0.5%)	> 0.99
Delirium, n (%)	3 (0.2%)	1 (0.1%)	2 (0.3%)	> 0.99
Naloxone, n (%)	83 (5.1%)	54 (6.6%)	29 (3.6%)	0.005
Mortality, n (%)	6 (0.4%)	3 (0.4%)	3 (0.4%)	> 0.99
Patient cost, median (Q1, Q3)	14020 (10611, 18876)	14837 (11053, 19263)	13415 (10340, 18349)	< 0.001
Length of stay, median (Q1, Q3)	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	0.08

IMV, invasive mechanical ventilation; NIV, noninvasive ventilation.

Figure 2—Odds ratio estimates for invasive mechanical ventilation within 3 days postsurgery in full cohort models.



deterioration on the day of surgery and an additional analysis comparing early with late NIV use.

How could these findings be explained? First, in this database it was challenging to differentiate fully prophylactic NIV (in the absence of any signs of respiratory distress) from NIV treatment for a patient experiencing early respiratory deterioration. As such, benefit in patients receiving NIV prophylactically could have been obscured by adverse outcomes in other subgroups. Second, we could not identify the group of patients with CPAP use before surgery. In a matched-cohort study, Mutter et. al. found that patients with a preoperative diagnosis of OSA and prescription for CPAP were less than half as likely to experience cardiovascular complications, compared to those who received a diagnosis after surgery.[37] Third, given the low rate of intubations and complications in both groups, it appears likely that patients who are truly at high risk for postoperative complications represent only a small proportion of all those with OSA undergoing surgery, and we did not have enough information to ascertain the at-risk subgroup. Fourth, although some studies have found beneficial effects of early CPAP on hypoxemia and early respiratory complications after extubation, several other studies, including a meta-analysis, suggested that there is no significant difference in the postoperative complications between CPAP users and nonusers, when CPAP was used acutely in the postoperative period. Last, several studies have shown that postoperative compliance with CPAP is low, and this may contribute to the apparent lack of benefit.[9] Supporting this hypothesis, one recent study showed that supervised CPAP treatment early after surgery improves the physiological consequences of sleep disorder breathing and ameliorates the respiratory depressant effects of opioids.[38] Our study has several strengths. This is one of the few large

Figure 3—Odds ratio estimates for invasive mechanical ventilation within 3 days postsurgery for patients with no arterial blood gas or chest x-ray on day of surgery.

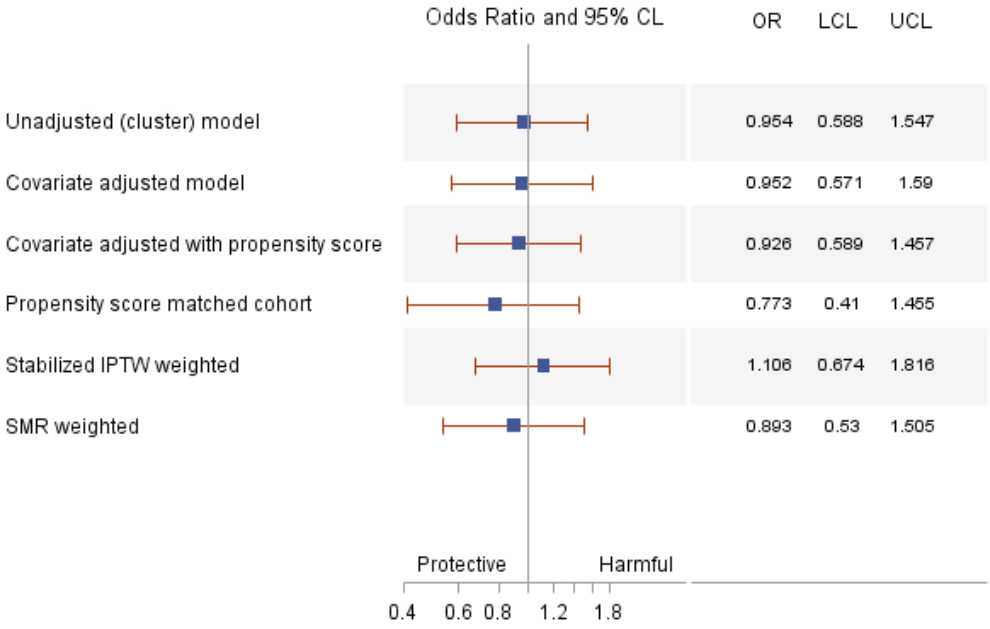


Table 5—Sensitivity analysis: outcomes in propensity matched sample for early postoperative noninvasive ventilation in patients with no arterial blood gas or chest x-ray on day of surgery.

	Overall (n = 1,030)	Early Postop NIV2 (n = 515)	No Early Postop NIV2 (n = 515)	p
IMV within 3 days, n (%)	45 (4.4%)	20 (3.9%)	25 (4.9%)	0.45
IMV prolonged, n (%)	11 (1.1%)	4 (0.8%)	7 (1.4%)	0.36
Acute coronary syndrome/myocardial infarction, n (%)	4 (0.4%)	1 (0.2%)	3 (0.6%)	0.32
Atrial and ventricular arrhythmias, n (%)	124 (12.0%)	67 (13.0%)	57 (11.1%)	0.34
Atrial fibrillation/flutter, n (%)	22 (2.1%)	14 (2.7%)	8 (1.6%)	0.20
Exacerbations of heart failure, n (%)	15 (1.5%)	6 (1.2%)	9 (1.8%)	0.44
Cardiac arrest, n (%)	4 (0.4%)	1 (0.2%)	3 (0.6%)	0.62
Delirium, n (%)	3 (0.3%)	2 (0.4%)	1 (0.2%)	> 0.99
Naloxone, n (%)	61 (5.9%)	35 (6.8%)	26 (5.1%)	0.24
Mortality, n (%)	3 (0.3%)	0 (0.0%)	3 (0.6%)	0.25
Patient cost, median (Q1, Q3)	13184 (10070, 18240)	15381 (11619, 19675)	14234 (10878, 19348)	0.08
Length of stay, median (Q1, Q3)	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	0.17

IMV, invasive mechanical ventilation; NIV, noninvasive ventilation.

observational studies describing the postoperative use of NIV and its association with outcomes in patients with OSA undergoing bariatric surgery. The analysis included more than 160 geographically and structurally diverse US hospitals that perform bariatric procedures. We have used both ICD-9 and billing/charge code data to assess ventilator utilization, which provide a more complete ascertainment of NIV use, because it was based on documentation by a respiratory therapist. This allows more accurate estimate of NIV use than databases such as the National Inpatient Sample, which relies solely on ICD-9 code.[30] We also employed state-of-the-art analytic methods, and evaluated the validity of our findings, using three sensitivity analyses. In addition to the common techniques for adjustment, we used hierarchical multivariable regression and propensity scores for matching, and two weighted analyses to address residual confounding. We adjusted for both the typical variables available in the administrative datasets, and also for important medications and laboratory tests that can contribute to outcomes or indicate disease severity.

The study also has a number of limitations. First, we rely on existing diagnosis codes to identify patients with OSA. A large study from Canada that assessed the accuracy of ICD-9 codes for the diagnosis of OSA found that the codes have low sensitivity (9%) and high specificity (98%).[39]

However, the biggest limitation associated with this pattern of sensitivity and specificity is on the ability to estimate the true prevalence of OSA. In contrast, studies such as ours, which analyzes a cohort of patients with a diagnosis of OSA

(representing all patients with that diagnosis) should be less affected by misclassification bias, thus rendering valid results.[40] Furthermore, patients undergoing bariatric surgeries are more likely to be screened for OSA and providers taking care of this group of patients are more likely to be aware of this diagnosis and code appropriately. Additionally, we found a 50% prevalence of OSA, which is within the range previously reported for bariatric surgery patients (36% to 70%). Second, we did not have information on whether patients used NIV preoperatively to optimize their condition, or whether there could have been "carryover" effects of its use or withdrawal in the hospital. Third, we lacked information on the actual use of NIV postoperatively (compliance); and, from prior studies, we know that compliance and tolerance with NIV can be poor, especially if this is a new therapy. Fourth, we did not have information on the severity of OSA. We have addressed this issue by carefully adjusting for factors known to be associated with OSA severity, such as morbid obesity, age, sex, and multiple comorbidities including pulmonary hypertension, COPD, congestive heart failure, and diabetes mellitus and we took into account medications that can have a differential effect due to severity of OSA. Because of the elective nature of the procedure, the screening guidelines, and recommendations for optimization before the bariatric surgery,[21,22] we assume that sick/high-risk patients will not be considered for surgery.

In this large observational study, we found that one in five patients with OSA undergoing bariatric surgery received early NIV, and the rates of NIV use varied largely across the hospitals. Although we could not make a clear distinction between prophylactic use of NIV and early treatment of respiratory deterioration, our results suggest that early use of NIV was not associated with better outcomes, including intubation and mortality rates. Properly designed controlled trials will be necessary to provide more definitive answers to this important clinical question.

ABBREVIATIONS

ABG, arterial blood gas
BIPAP, bilevel pressure support
COPD, chronic obstructive pulmonary disease
CPAP, continuous positive airway pressure
CXR, chest x-ray
ICD, International Classification of Diseases
IMV, invasive mechanical ventilation
IQRs, interquartile ranges
NIV, noninvasive ventilation
OSA, obstructive sleep apnea
SMR, standardized mortality ratio

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