Sleep-Disordered Breathing and Postoperative Outcomes After Elective Surgery

Analysis of the Nationwide Inpatient Sample

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Background: Systematic screening and treatment of sleep-disordered breathing (SDB) or obstructive sleep apnea (OSA) in presurgical patients would impose a significant cost burden; therefore, it is important to understand whether SDB is associated with worse postoperative outcomes. We sought to determine the impact of SDB on postoperative outcomes in patients undergoing four specific categories of elective surgery (orthopedic, prostate, abdominal, and cardiovascular). The primary outcomes were in-hospital death, total charges, and length of stay (LOS). Two secondary outcomes of interest were respiratory and cardiac complications.

Methods: Data were obtained from the Nationwide Inpatient Sample database. Regression models were fitted to assess the independent association between SDB and the outcomes of interest.

Results: The cohort included 1,058,710 hospitalized adult patients undergoing elective surgeries between 2004 and 2008. SDB was independently associated with decreased mortality in the orthopedic (OR, 0.65; 95% CI, 0.45-0.95; $P = .03$), abdominal (OR, 0.38; 95% CI, 0.22-0.65; $P = .001$), and cardiovascular surgery groups (OR, 0.54; 95% CI, 0.40-0.73; $P < .001$) but had no impact on mortality in the prostate surgery group. SDB was independently associated with a small, but statistically significant increase in estimated mean LOS by 0.14 days ($P < .001$) and estimated mean total charges by \$860 ($P < .001$) in the orthopedic surgery group but was not associated with increased LOS or total charges in the prostate surgery group. In the abdominal and cardiovascular surgery groups, SDB was associated with a significant decrease in adjusted mean LOS of 1.1 days and 0.35 days, respectively ($P < .001$ for both groups), and adjusted mean total charges of \$3,814 and \$4,592, respectively ($P < .001$ for both groups). SDB was independently associated with a significantly increased OR for emergent intubation and mechanical ventilation, noninvasive ventilation, and atrial fibrillation in all four surgical categories. Emergent intubation occurred significantly earlier in the postoperative course in patients with SDB. In the subgroup of patients requiring emergent intubation, LOS, total charges, pneumonias, and in-hospital death were significantly higher in those without SDB.

Conclusions: In this large national study, despite the increased independent association of SDB with postoperative cardiopulmonary complications, the diagnosis of SDB was not independently associated with an increased rate of in-hospital death. SDB had a mixed impact on LOS and total charges by surgical category.

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Abbreviations: CCI = Charlson Comorbidity Index; CCS = Clinical Classifications Software; ICD-9-CM = *International Classification of Diseases, Ninth Revision, Clinical Modification*; LOS = length of stay; NIS = Nationwide Inpatient Sample; NIV = noninvasive ventilation; SDB = sleep-disordered breathing

Sleep-disordered breathing (SDB) is increasingly recognized as a possible risk factor for adverse perioperative outcomes.¹⁻⁶ Given the important implications of untreated SDB, the American Society of Anesthesiologists recommends screening patients prior to

surgery for SDB and implementing treatment if SDB is present.⁷ However, despite this growing awareness, there is a paucity of large-scale studies that examined the impact of SDB on postoperative outcomes. Moreover, given that systematic screening would impose a

significant cost burden, it is important to understand whether screening and perioperative treatment of SDB improves outcomes.

To date, most studies have focused on developing effective screening tools for SDB in the preoperative population^{1,8-10} or have outlined postoperative outcomes of patients with SDB in a relatively small population at single centers.^{1,2,4,5} These studies have shown worse postoperative outcomes in patients with SDB, such as increased rates of hypoxemia, respiratory failure, ICU transfers, increased hospital lengths of stay (LOSs), encephalopathy, and postoperative infections.^{1,2,4-6,11,12} The generalizability of these studies is limited by the small sample sizes and single-institution experiences. Memtsoudis et al¹³ used a large, national database to evaluate the effect of SDB on pulmonary outcomes in patients undergoing both elective and nonelective orthopedic and general surgical procedures. They reported significantly worse pulmonary outcomes, including aspiration pneumonia, ARDS, and emergent endotracheal intubation, in patients with SDB compared with those without SDB.

The association of SDB with postoperative outcomes, such as in-hospital death, total charges, and LOS, in patients undergoing elective surgery remains largely unexamined. Moreover, the effect of SDB on postoperative outcomes in specific elective procedures, such as orthopedic, urologic, abdominal, and cardiovascular surgeries, remains poorly characterized. Given that serious postoperative events are relatively uncommon occurrences, large nationally representative databases are unique and necessary tools to examine the association of SDB with important postoperative complications.

To that end, we analyzed the Nationwide Inpatient Sample (NIS) database to determine the impact of SDB

on postoperative outcomes in patients undergoing four specific types of elective surgery: orthopedic, prostate, abdominal, and cardiovascular. We quantified the impact of SDB diagnosis on in-hospital death, total charges, LOS, respiratory outcomes, and cardiac outcomes. We hypothesized that SDB would be independently associated with worse postoperative outcomes after controlling for comorbid conditions and demographic characteristics. A secondary aim of the study was to explore the impact of the American Society of Anesthesiologists 2006 practice guidelines on postoperative outcomes in patients with SDB.

MATERIALS AND METHODS

Data Source

Data were obtained from the NIS database, which is one of several databases that form the Healthcare Utilization Project, is sponsored by the Agency for Healthcare and Research Quality, and is the largest all-payer database in the United States. The NIS database has been used in a variety of research studies¹⁴⁻¹⁶ because it contains information on ~8 million hospitalizations per year from 1,050 hospitals in 44 states. The data approximate a 20% stratified sample of hospitals in the United States and have been collected annually since 1988.¹⁷ Each hospitalization record includes common demographic variables, hospital characteristics, and clinical data coded according to the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM). This study was approved by The University of Chicago Institutional Review Board (BSD/UCH IRB approval # 10-567-E).

Patient Cohort

The cohort was derived from all hospital admission records in the NIS database for adults aged ≥ 18 years who underwent elective orthopedic, prostate, abdominal, and cardiovascular surgery between 2004 and 2008. We selected records from the most recent 5 years in the NIS database to avoid significant changes in practice patterns. At the time of this study, 2008 was the last year that had become available for data extraction in the database. Patients were stratified by whether they received a diagnosis of SDB. ICD-9-CM codes were used to characterize SDB and surgical procedures (e-Appendix 1). The percentage of each surgical procedure within each surgical category is outlined in e-Appendix 1. Patients undergoing urgent or emergency surgery were excluded.

Patient Data

Patient demographics included age, sex, self-reported race/ethnicity, Charlson Comorbidity Index (CCI) score, income by quartile, health insurance source (ie, Medicare, Medicaid, private), teaching or nonteaching hospital status, and US region (northeast, south, west, midwest/central). The information about race was missing in ~27% of cases because some participating states restrict data collection on race. The CCI is used to assign severity to a patient's comorbid conditions. Common comorbid conditions are assigned varying weights, and the sum of the patient's score indicates his or her cumulative comorbid condition, with higher scores indicating increased comorbidity.¹⁸ Income was divided into quartiles, with 1 being the poorest and 4 being the wealthiest. Income data were obtained from zip codes and demographic data from Nielson online demographic services.¹⁹

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The primary outcomes compared between patients with and patients without SDB were cost in total hospital charges, LOS, and in-hospital death. Secondary respiratory outcomes were emergent endotracheal intubation and mechanical ventilation, CPAP/non-invasive ventilation (NIV) during hospitalization, tracheostomy, pneumonia, and respiratory failure. The NIS database does not provide detailed information about the timing of extubation after surgery; therefore, we were unable to identify patients who were not immediately extubated in the operating room or the postanesthesia care unit. Secondary cardiac outcomes included atrial fibrillation, cardiac rhythm conversion, and percutaneous coronary procedures.

Data Extraction

Total charges, LOS, and in-hospital death are variables available in the NIS database. Secondary outcomes were derived from ICD-9-CM and Clinical Classifications Software (CCS) codes (e-Appendix 2). CCS codes provide a classification scheme that facilitates analyzing data on procedures and diagnoses. CCS codes condense ICD-9-CM codes into fewer clinically meaningful groups that are easier to analyze.²⁰

Statistical Analysis

For unadjusted comparisons between patients with and patients without SDB, continuous variables (age, LOS, and total charges) were presented as the mean $\pm$ SD and compared with Student *t* test. All other categorical variables were summarized as percentages and compared with χ^2 test. Generalized linear models with log-link and γ -distributed errors were fitted to assess the independent association between SDB and log-transformed LOS and log-transformed total charges. We used the iteratively reweighted least squares method for maximum likelihood estimation of the model parameters. There is substantial statistical literature that recommends using generalized linear model techniques when modeling health-care costs and LOS because of unique features of such data, namely that they tend to be differentially dispersed around the mean (heteroskedastic) and prone to large outliers (right skewed).^{21,22} Mean adjusted LOS and total charges for patients with and without SDB were then estimated from the generalized linear models.

We constructed logistic regression models for outcomes that were dichotomous to determine the independent association of SDB and the outcomes of interest. Independent variables introduced in the generalized linear models and logistic regression models were age by quartiles, sex, type of health insurance, income by quartiles, CCI score, type of surgical procedure, year of the surgical procedure, hospital teaching status, US region where the hospital is located, and weekend admission. Race was not included in the models because it was missing for about 27% of admissions. We did not introduce obesity into the models because only 5% of patients in the cohort had a diagnosis of obesity, which likely is the result of significant underreporting. Moreover, BMI is not available in the NIS database.

We also examined for collinearity among variables introduced in the generalized linear models as well as in the logistic regression models. The percentage of patients who were dropped from the regression models because of a missing variable was negligible (between 1.5% and 2.5%). To measure model discrimination and the goodness of fit, several statistics were examined, including deviance, Pearson χ^2 , Akaike information criterion, Bayesian information criterion, and pseudo R^2 statistics. Specifically, the deviance statistic measures how close the predicted values from the fitted model match the actual values from the raw data. If the proposed model is a good approximation of the truth, then the deviance should be relatively small (ie, <1). Lower values of the Akaike and

the Bayesian information criterion statistics also indicate better-fitted models. To assess the impact of the American Society of Anesthesiologists 2006 practice guidelines,⁷ we compared outcomes in patients undergoing surgery during the 2 years prior to the publication of the guidelines (2004-2005) to the 2 years after its publication (2007-2008). Stata 11 (StataCorp LP) statistical software was used for all analyses.

RESULTS

Demographics

The cohort included 1,058,710 patients undergoing elective surgeries between 2004 and 2008. The surgical categories included 783,723 orthopedic, 67,848 prostate, 79,101 abdominal, and 128,038 cardiovascular. SDB was reported in 43,502 (5.6%) of orthopedic, 2,779 (4.1%) of prostate, 2,633 (3.3%) of abdominal, and 6,006 (4.7%) of cardiovascular cases. The prevalence of SDB diagnosis increased progressively in each surgical group from 2004 to 2008 (Fig 1). Patient demographics for each surgical category are summarized in Table 1. The prevalence of CCI scores 3 to 4, indicating an increased burden of comorbid disease, were significantly elevated among patients with SDB, except in the abdominal surgical group. In general, patients with SDB were younger, predominantly men, had increased CCI, and had a lower percentage of Medicare coverage. Additionally, patients with SDB were more likely to undergo elective surgery at a teaching hospital.

Unadjusted Comparisons

In the unadjusted comparisons, patients with SDB incurred significantly more total charges in the orthopedic and prostate surgery groups (Table 2). Conversely, they incurred significantly fewer charges in the abdominal and cardiovascular surgery groups. Patients with SDB had a slight but significantly increased LOS in the orthopedic surgery group,

FIGURE 1. Prevalence of SDB in all surgical categories from 2004 to 2008. For each category, there was an increase in reporting SDB over the 5-year period. The year-to-year increase in SDB reporting was also significant in each surgical category (all $P < .01$). SDB = sleep-disordered breathing.

Table 1—Demographic Data for Surgical Categories Based on SDB Status

Variable	Orthopedic Surgery (n = 783,723)		Prostate Surgery (n = 67,848)		Abdominal Surgery (n = 79,101)		Cardiovascular Surgery (n = 128,038)	
	No SDB	SDB	No SDB	SDB	No SDB	SDB	No SDB	SDB
No. patients	740,221	43,502	65,069	2,779	76,468	2,633	122,032	6,006
% within surgical category	94.4	5.6	95.9	4.1	96.7	3.3	95.3	4.7
Age, y	64.3 ± 13.2	62.2 ± 10.1	62.2 ± 8.2	61.4 ± 7.7	64.4 ± 15.5	59.4 ± 13.5	64.8 ± 11.1	62.1 ± 9.8
Female sex	60.3	43.3	0	0	53.2	39.9	30.6	16.9
Race								
White	86.3	88	80.3	86.2	80.7	80.6	84	88
Black	6.6	6.9	11	7.9	9.6	11.7	5.7	4.4
Hispanic	3.7	2.7	4.7	2.8	5.4	4.4	5.7	3.9
Other	3.4	2.4	4	3.1	3.3	4.3	4.7	3.7
Charlson Comorbidity Index score								
0	67.5	49.6	77.6	66.7	56.2	40	40	30.3
1	25.2	34.9	18.1	25.8	21.8	32.1	36.5	39.7
2	5.5	11.5	3	5	5.6	11.7	15.5	20.1
3	1.4	2.8	0.9	1.9	10.9	8.4	5.2	6.3
≥ 4	0.5	1.1	0.4	0.7	5.6	7.8	2.9	3.6
Insurance type								
Medicare	52.2	44.5	33.9	32.6	53.4	40.1	52.1	42.7
Private	40	48.2	60.4	63.5	38.1	48.2	38.6	49.5
Medicaid	2.9	2.6	1.6	1.1	3.8	4.2	4.1	3
Other	5	4.7	4.1	2.9	4.8	7.5	5.1	4.8
Income quartile								
First	21.1	19.7	18.2	14.7	24.1	20.9	26.2	23.9
Second	27.3	27.3	24	24.2	27.5	25.3	28.1	28.1
Third	26.5	28	26.3	28.9	25.2	28	25	26.5
Fourth	25.1	25	31.6	32.2	23.2	25.9	20.6	21.6
Teaching hospital	44.6	47.2	59.8	60.9	46.2	51.9	55	56.3
Hospital region								
Northeast	20	14.8	21.5	17.2	21	16.4	15.6	11.6
South	38.3	36.8	37.9	35.6	42.6	44.1	46.2	42.8
West	12.2	14.9	14.6	17.3	10.1	11	10.6	12.6
Midwest/north central	29.6	33.6	26	29.9	26.3	28.5	27.5	32.9

Data are presented as mean ± SD or %. SDB = sleep-disordered breathing.

whereas in the abdominal and cardiovascular surgery groups, they had a significantly shortened LOS. There was a significantly lower rate of in-hospital death in patients with SDB than in those without SDB in the orthopedic (0.07% vs 0.13%, $P < .01$), abdominal (0.5% vs 1.5%, $P < .01$), and cardiovascular (0.8% vs 1.9%, $P < .01$) surgery groups.

Across all surgical groups, there were significantly increased rates of emergent intubation and mechanical ventilation, use of CPAP/NIV, and respiratory failure in patients with SDB compared with those without SDB (Fig 2, Table 2). There were significantly lower rates of pneumonia in patients with SDB in the abdominal and cardiovascular surgery groups. Rates of tracheostomy did not differ between patients with and patients without SDB in the orthopedic, prostate, and abdominal surgery groups. There were significantly fewer tracheostomies in patients with SDB in the cardiovascular surgery group. The proportion of patients with atrial fibrillation and SDB was signif-

icantly increased in the orthopedic and prostate surgery groups. Rates of cardioversion and percutaneous coronary procedures were not significantly different between patients with and patients without SDB in all four surgical categories.

Adjusted Comparisons

In generalized linear models, after adjusting for the covariates, SDB was independently associated with a small, but statistically significant increase in estimated mean LOS by 0.14 days ($P < .001$) and estimated mean total charges by \$860 ($P < .001$) in the orthopedic surgery group. SDB was not associated with increased LOS or total charges in the prostate surgery group. In the abdominal surgery group, SDB was associated with a decrease in an adjusted mean LOS of 1.1 days ($P < .001$) and an adjusted mean total charge of \$3,814 ($P < .001$). Similarly, in the cardiovascular group, SDB was associated with a decrease

Table 2—Unadjusted Outcomes by Surgical Category and SDB Status

Variable	Orthopedic Surgery		Prostate Surgery		Abdominal Surgery		Cardiovascular Surgery	
	No SDB	SDB	No SDB	SDB	No SDB	SDB	No SDB	SDB
No. patients	740,221	43,502	65,069	2,779	76,468	2,633	122,032	6,006
% within surgical category	94.4	5.6	95.9	4.1	96.7	3.3	95.3	4.7
Total charges, \$	35,496 ± 20,219	38,548 ± 19,654 ^a	26,217 ± 16,496	27,829 ± 17,625 ^a	39,977 ± 49,133	37,934 ± 33,448 ^a	85,784 ± 64,959	81,285 ± 42,270 ^a
Length of stay, d	3.47 ± 2.13	3.57 ± 1.79 ^a	2.49 ± 2.11	2.47 ± 1.96	7.10 ± 6.63	5.78 ± 4.53 ^a	7.88 ± 6.66	7.12 ± 4.13 ^a
In-hospital death	0.13	0.07 ^a	0.1	0.1	1.5	0.5 ^a	1.9	0.8 ^a
Respiratory complications								
Emergent intubation	0.3	3.9 ^a	0.3	3.5 ^a	3.3	6.6 ^a	7	11.4 ^a
CPAP/NIV	0.1	3.5 ^a	0	2.9 ^a	0.4	4 ^a	0.9	4.7 ^a
Respiratory failure	0.5	1.5 ^a	0.5	1.2 ^a	4.2	5.1 ^b	10.6	13.6 ^a
Pneumonia	0.7	0.7	0.4	0.5	3.4	2.5 ^a	3	2.5 ^c
Tracheostomy	0.01	0.01	0	0	0.4	0.2	0.8	0.3 ^a
Cardiac complications								
Atrial fibrillation	4.9	6.7 ^a	2.9	5.8 ^a	8.3	9.2	24.5	24.3
Cardioversion	0.01	0	0	0	0.02	0	0.1	0.2
Coronary procedures	0.1	0.2	0.1	0.1	0.4	0.2	32.7	32.3

Data are presented as mean ± SD or %. NIV = noninvasive ventilation. See Table 1 legend for expansion of other abbreviation.

^a*P* < .01 comparing no SDB to SDB groups.

^b*P* = .03 comparing no SDB to SDB groups.

^c*P* = .02 comparing no SDB to SDB groups.

FIGURE 2. Unadjusted outcomes for intubation, respiratory failure, CPAP/noninvasive ventilation use, and atrial fibrillation in patients with and without SDB. * $P < .001$; † $P = .03$. See Figure 1 legend for expansion of abbreviation.

in adjusted mean LOS of 0.35 days ($P < .001$) and an adjusted mean total charge of \$4,592 ($P < .001$) (Fig 3, Table 3). On the basis of the various statistics measured, the model discrimination and model fit were excellent in all four surgical categories mostly because of the very large sample sizes.

SDB was independently associated with decreased mortality in the orthopedic (OR, 0.65; 95% CI, 0.45-0.95; $P = .03$), abdominal (OR, 0.38; 95% CI, 0.22-0.65; $P = .001$), and cardiovascular (OR, 0.54; 95% CI, 0.40-0.73; $P < .001$) surgery groups. SDB had no impact on mortality in the prostate surgery group (Table 3). SDB was independently associated with a significantly increased OR for emergent intubation

FIGURE 3. Mean adjusted length of stay and total charges in various surgical categories in patients with and without SDB. * $P < .001$. See Figure 1 legend for expansion of abbreviation.

and mechanical ventilation, CPAP/NIV, and atrial fibrillation in all four surgical categories. SDB was independently associated with a significantly increased OR for respiratory failure in all surgical groups except abdominal (Table 3). There was no evidence that the American Society of Anesthesiologists 2006 practice guidelines had any impact on postoperative outcomes according to the regression models comparing the 2 years before and the 2 years after the publication of these guidelines (data not shown).

Outcomes of Patients Requiring Emergent Intubation and Mechanical Ventilation

In unadjusted analyses, we examined the impact of emergent intubation and mechanical ventilation on outcomes between patients with and patients without SDB (Table 4). Across all four surgical categories, the LOS, total charges, pneumonias, and in-hospital death increased significantly more in patients without SDB requiring emergent intubation and mechanical ventilation than those with SDB requiring the same intervention. Among the four surgical categories, unadjusted analysis demonstrated that emergent intubation in patients with SDB was associated with an increase in the LOS by about 1 to 2.5 days, an increase in total charges by about \$8,000 to \$26,000, an increase in pneumonias by about 2% to 5.4%, and an increase in

Table 3—Regression Modeling to Estimate Adjusted Risk of Outcomes Associated With SDB

Outcome	Orthopedic	Prostate	Abdominal	Cardiovascular
Length of stay				
Regression coefficient for SDB (95% CI)	0.038 (0.03 to 0.05)	0.02 (−0.01 to 0.05)	−0.16 (−0.2 to −0.13)	−0.05 (−0.07 to −0.03)
P value	< .001	.18	< .001	< .001
Total charges				
Regression coefficient for SDB (95% CI)	0.024 (0.02 to 0.03)	0.02 (−0.004 to 0.043)	−0.1 (−0.14 to −0.06)	−0.06 (−0.07 to −0.04)
P value	< .001	.11	< .001	< .001
In-hospital death				
OR (95% CI)	0.65 (0.45 to 0.95)	1.04 (0.25 to 4.34)	0.38 (0.22 to 0.65)	0.54 (0.40 to 0.73)
P value	.03	.9	.001	< .001
Respiratory complications				
Emergent intubation				
OR (95% CI)	14.3 (13.3 to 15.3)	10.3 (8.0 to 13.3)	2.01 (1.7 to 2.4)	1.80 (1.65 to 1.95)
P value	< .001	< .001	< .001	< .001
CPAP/NIV				
OR (95% CI)	50.6 (45.4 to 56.5)	85.2 (52.2 to 139.2)	10.3 (8.0 to 13.4)	5.5 (4.7 to 6.3)
P value	< .001	< .001	< .001	< .001
Respiratory failure				
OR (95% CI)	3.2 (2.9 to 3.5)	2.51 (1.75 to 3.62)	1.13 (0.94 to 1.37)	1.30 (1.20 to 1.40)
P value	< .001	< .001	.19	< .001
Pneumonia				
OR (95% CI)	1.06 (0.94 to 0.19)	1.3 (0.74 to 2.30)	0.71 (0.56 to 0.92)	0.85 (0.72 to 1.01)
P value	.34	.35	.01	.06
Tracheostomy				
OR (95% CI)	0.87 (0.385 to 2.0)	2.2 (0.28 to 17.7)	0.59 (0.26 to 1.34)	0.38 (0.23 to 0.63)
P value	.75	.45	.20	< .001
Cardiac complications				
Atrial fibrillation				
OR (95% CI)	1.55 (1.49 to 1.62)	2.17 (1.82 to 2.58)	1.6 (1.35 to 1.81)	1.12 (1.05 to 1.20)
P value	< .001	< .001	< .001	.001
Cardioversion				
OR (95% CI)	0.89 (0.21 to 3.8)	No events	No events	1.29 (0.65 to 2.55)
P value	.88			.46
Coronary procedures				
OR (95% CI)	1.08 (0.84 to 1.4)	1.04 (0.32 to 3.34)	0.47 (0.18 to 1.28)	0.94 (0.89 to 1.00)
P value	.52	.94	.14	.06

Generalized linear modeling for continuous variables (length of stay and total charges) and multivariate logistic regression for dichotomous variables were used to estimate regression coefficients or ORs for the presence of SDB after adjusting for age, sex, Charlson Comorbidity Index, insurance status, geographic region, teaching institution, income, weekend admission, year of surgery, and surgical procedure code. See Table 1 and 2 legends for expansion of abbreviations.

in-hospital death by 0.9% to 4.4%. In contrast, emergent intubation in patients without SDB was associated with significantly worse outcomes, such as an increase in the LOS by about 6.5 to 11.7 days, an increase in total charges by about \$60,000 to \$100,000, an increase in pneumonias by about 11% to 24%, and an increase in in-hospital death by 6.6% to 24% (Table 4).

We constructed regression models to assess whether emergent intubation in patients without SDB was independently associated with worse outcomes (Fig 4, Table 5). After adjusting for age, sex, CCI, hospital teaching status, and year of surgery, patients without SDB who required emergent intubation had significantly worse outcomes than those with SDB who required emergent intubation.

The use of CPAP/NIV during the hospital course was significantly lower in patients without SDB requiring

emergent intubation and mechanical ventilation. Of note, CPAP/NIV use during the hospitalization was not recorded in any patient who did not require emergent intubation and mechanical ventilation, regardless of the SDB status (Table 4). Across all four surgical categories, a significantly higher proportion of patients with SDB required emergent intubation and mechanical ventilation on the day of surgery or the first post-operative day compared with patients without SDB (Table 4).

DISCUSSION

We show for the first time, to our knowledge, that the diagnosis of SDB is not independently associated with a clinically significant increase in in-hospital death,

Table 4—Unadjusted Outcomes Based on the Diagnosis of SDB and Need for Endotracheal Intubation in All Four Surgical Categories

Outcome	No SDB		Sleep SDB	
	No Intubation	Intubation	No Intubation	Intubation
Orthopedic surgery, No. patients	738,079	2,142	41,806	1,696
Total charges, \$	35,321 ± 19,315	95,991 ± 95,410 ^a	38,260 ± 19,045	45,635 ± 30,254 ^b
Length of stay, d	3.45 ± 2.00	10.9 ± 12.06 ^a	3.53 ± 1.68	4.60 ± 3.37 ^b
In-hospital death	0.06	24.17 ^a	0.03	0.94 ^b
CPAP/NIV	0	23.53 ^a	0	89.98 ^b
Pneumonia	0.59	25.16 ^a	0.63	2.95 ^b
Respiratory failure	0.28	61.76 ^a	1.01	13.33 ^b
Intubation on day 0 or day 1	NA	54.6	NA	84.8 ^c
Prostate surgery, No. patients	64,846	223	2,681	98
Total charges, \$	26,006 ± 15,063	87,599 ± 98,363 ^a	27,358 ± 15,848	40,732 ± 42,215 ^b
Length of stay, d	2.46 ± 1.96	10.16 ± 11.6 ^a	2.42 ± 1.88	3.64 ± 3.31 ^b
In-hospital death	0.04	9.87 ^a	0	2.04 ^b
CPAP/NIV	0	9.87 ^a	0	81.63 ^b
Pneumonia	0.32	14.35 ^a	0.45	2.4 ^b
Respiratory failure	0.23	64.57 ^a	0.52	20.41 ^b
Intubation on day 0 or day 1	NA	78.4	NA	87.3 ^c
Abdominal surgery, No. patients	73,922	2,546	2,460	173
Total charges, \$	36,643 ± 39,049	136,858 ± 136,213 ^a	36,229 ± 28,121	62,138 ± 71,947 ^b
Length of stay, d	6.71 ± 5.65	18.40 ± 16.20 ^a	5.60 ± 4.08	8.44 ± 8.30 ^b
In-hospital death	0.7	24.99 ^a	0.2	4.62 ^b
CPAP/NIV	0	10.76 ^a	0	60.12 ^b
Pneumonia	2.63	25.49 ^a	2.15	7.51 ^b
Respiratory failure	1.97	69.52 ^a	3.01	34.68 ^b
Intubation on day 0 or day 1	NA	45.4	NA	78.8 ^c
Cardiovascular surgery, No. patients	113,462	8,570	5,319	687
Total charges, \$	81,366 ± 55,825	144,397 ± 123,128 ^a	78,438 ± 42,516	103,311 ± 70,682 ^b
Length of stay, d	7.42 ± 5.49	14.03 ± 12.88 ^a	6.87 ± 3.57	9.09 ± 6.79 ^b
In-hospital death	1.15	11.73 ^a	0.43	3.36 ^b
CPAP/NIV	0	12.58 ^a	0	41.34 ^b
Pneumonia	2.24	13.64 ^a	2.01	6.26 ^b
Respiratory failure	7.07	57.65 ^a	9.4	46.14 ^b
Intubation on day 0 or day 1	NA	60.8	NA	65.0 ^c

Data are presented as mean ± SD or % unless otherwise indicated. day 0 = day of surgery; day 1 = postoperative day 1; NA = not applicable. See Table 1 and 2 legends for expansion of other abbreviations.

^a*P* < .001 comparing no SDB/no intubation with no SDB/intubation categories.

^b*P* < .001 comparing SDB/no intubation with SDB/intubation categories.

^c*P* < .001 comparing SDB/intubation with no SDB/intubation categories.

LOS, or total charges in a large, nationally representative cohort of patients undergoing various types of elective surgery. In patients undergoing elective orthopedic, abdominal, and cardiovascular surgeries, SDB was associated with a significant decrease in in-hospital mortality. Like previous studies,^{3-5,13} we found that the diagnosis of SDB was independently associated with increased rates of emergent endotracheal intubation and mechanical ventilation, CPAP/NIV use, and respiratory failure across all four surgical categories studied. The present study also extends previous findings by showing that the diagnosis of SDB is independently associated with atrial fibrillation. One novel finding of the present study is that a significantly larger proportion of patients with SDB required emergent endotracheal intubation early in their postoperative course compared with those without SDB.

The LOS, total charges, pneumonias, and in-hospital deaths increased dramatically more in patients without SDB requiring emergent intubation than in those with SDB requiring the same intervention.

The findings suggest that upper airway complications may be the main cause of respiratory failure and need for emergent intubation in patients with SDB. This speculation is supported by the fact that in patients with SDB, emergent intubation occurred earlier in their postoperative course. Moreover, we speculate that in patients with SDB, the primary reason for emergent intubation may have been related to a rapidly reversible upper airway complication in the setting of sedative and opioid administration in the immediate postoperative period. The fact that emergent intubation in patients with SDB led to a significantly less increase in LOS, total charges, pneumonias, and in-hospital

FIGURE 4. Mean adjusted length of stay and total charges in patients with and without SDB who required emergent endotracheal intubation. * $P < .001$. See Figure 1 legend for expansion of abbreviations.

deaths than in patients without SDB who also required emergent intubation supports this speculation. It is well known that patients with SDB have elevated pharyngeal closing pressures as well as decreased velopharyngeal and oropharyngeal cross-sectional areas, leading to increased upper airway instability in the postoperative setting compared with age- and BMI-matched control patients.^{23,24} Another possibility is that clini-

cians may have had a lower threshold for intubating patients with known SDB in the setting of postoperative respiratory complications. In the present analysis, patients without SDB who required emergent intubation had a significant increase in rates of in-hospital death, LOS, total charges, respiratory failure, and pneumonia. On average, they were intubated later in their postoperative course and had higher rates of pneumonia, and we suspect that their intubation was indicative of a global decline or complication that took much longer to recover from, resulting in worse outcomes.

Although SDB was independently associated with cardiopulmonary complications across all four surgical categories, it remains unclear why SDB was not independently associated with increased LOS, total charges, and in-hospital death. It is well-known from prior postoperative cohorts that patients with SDB are more obese than their counterparts without SDB.^{1,4,5,25} A growing body of literature has been reporting an obesity paradox such that in patients with a variety of illnesses, including postoperative patients, obesity is associated with reduced mortality.^{16,26-29} Although the phenomenon of the obesity paradox is not entirely understood, possible explanations in favor of causality have included earlier presentation to medical care as well as more optimal medical therapy,³⁰⁻³² cardioprotective metabolic effects of increased body fat,³³ and increased metabolic reserves.³⁴ Another invoked putative mechanism by which SDB could decrease mortality is ischemia preconditioning. Studies have reported that in patients with acute myocardial infarction, those with SDB and intermittent hypoxemia during sleep have less severe cardiac injury and better coronary collateral circulation.³⁵⁻⁴⁰ Therefore, it is

Table 5—Regression Modeling to Estimate Adjusted Risk of Outcomes Associated With No SDB Status in Patients Requiring Emergent Endotracheal Intubation

Outcomes in Patients Requiring Intubation	Orthopedic	Prostate	Abdominal	Cardiovascular
In-hospital death				
OR (95% CI)	25.0 (15.0-41.6)	4.18 (0.93-18.83)	5.18 (2.51-10.61)	3.06 (2.01-4.69)
P value	< .001	.06	< .001	< .001
Total charges				
Regression coefficient for no SDB (95% CI)	0.73 (0.67-0.78)	0.82 (0.57-1.08)	0.84 (0.69-0.99)	0.30 (0.24-0.37)
P value	< .001	< .001	< .001	< .001
Length of stay				
Regression coefficient for no SDB (95% CI)	0.78 (0.72-0.85)	1.01 (0.73-1.25)	0.79 (0.66-0.93)	0.36 (0.29-0.44)
P value	< .001	< .001	< .001	< .001
Respiratory failure				
OR (95% CI)	9.26 (7.81-11.02)	9.17 (4.85-17.24)	4.01 (2.86-5.61)	1.63 (1.39-1.92)
P value	< .001	< .001	< .001	< .001
Pneumonia				
OR (95% CI)	10.0 (7.30-13.51)	9.52 (2.15-41.66)	4.67 (2.60-8.40)	2.38 (1.73-3.27)
P value	< .001	.003	< .001	< .001

Generalized linear modeling for continuous variables (length of stay and total charges) and multivariate logistic regression for dichotomous variables were used to estimate regression coefficients or ORs in patients without SDB after adjusting for age, sex, Charlson Comorbidity Index, insurance status, teaching institution, and year of surgery. No SDB status in patients requiring intubation was independently associated with worse outcomes in all four surgical categories. See Table 1 legend for expansion of abbreviation.

plausible that SDB does not increase in-hospital mortality in the immediate postoperative setting despite the increased risk of upper airway complications. Although untreated severe SDB is strongly associated with increased cardiovascular mortality,⁴¹⁻⁴⁵ it remains unclear whether in the acute postoperative setting untreated SDB can also lead to increased cardiovascular mortality.

Another reason for lower postoperative mortality in patients with SDB could be that the diagnosis leads to early effective intervention, which decreases this adverse outcome, whereas the population without SDB includes patients with SDB who experience adverse outcomes because of failure to identify the condition. However, it is unlikely that the lower mortality in patients with SDB was related to better postoperative care because respiratory complications were more common in patients with SDB. Moreover, CPAP/NIV use during the hospitalization was not recorded in any patient with or without SDB who did not require intubation (Table 4). In patients with SDB, rates of CPAP/NIV use ranged from 2.9% to 4.7% across the four surgical categories, and CPAP/NIV use was only reported in patients requiring emergent intubation during their hospital course. Such a low use of CPAP/NIV in the postoperative setting in patients with SDB has been previously reported.^{5,46,47} In a recent randomized controlled trial of patients undergoing elective hip and knee arthroplasty, patients suspected of having moderate or severe SDB were randomized to auto-CPAP therapy during the postoperative period vs standard care. Empirical auto-CPAP therapy led to a 1-day increase in median LOS.⁴⁸ This study raises new questions about the role for empirical postoperative auto-CPAP therapy.

In general, tracheostomies were rare in all four surgical categories. The only significant difference was between patients with and patients without SDB in the cardiovascular surgery group. We speculate that tracheostomies were less common in patients with SDB in this group because they had significantly fewer pneumonias. It is also possible that a higher rate of CPAP/NIV use in the SDB group decreased the need for prolonged mechanical ventilation and, ultimately, the need for tracheostomy. In this analysis, SDB was not independently associated with an increased risk of pneumonia in patients undergoing elective surgery. Although Memtsoudis et al¹³ found an increased risk of pneumonia in patients with SDB, the cohort also included emergent and urgent surgeries. In fact, 47% of the orthopedic and 65% of the abdominal surgery cohorts underwent urgent or emergent surgeries. Patients undergoing nonelective surgeries are probably at higher risk of pneumonia than those undergoing elective surgeries.

This study has several limitations that are mainly inherent to the analysis of large administrative databases. Some of these limitations include the inability to ascertain the presence or absence of SDB and its severity, lack of information about home CPAP therapy or CPAP/NIV adherence during the postoperative period, and lack of information regarding complications after hospital discharge. The NIS database also lacks information about advanced services, such as critical care, step down, and telemetry. Moreover, the database lacks information about readmissions and long-term outcomes. It was not possible to ascertain whether atrial fibrillation was present before surgery or developed after surgery.

Additional limitations include a possibility of coding error or reporting bias; however, there is no reason that these errors or biases should differ among patients categorized as having or not having SDB. We also could not ascertain whether the diagnostic codes for SDB were part of the admission or discharge diagnoses; therefore, it is conceivable that respiratory complications could have led to the new discharge diagnosis of SDB. Although prevalence estimates of SDB from community-based studies range from 5% to 28% in women and 17% to 26% in men,⁴⁹⁻⁵² the prevalence of clinically significant and symptomatic SDB in the community is significantly lower at 2% to 9%. It is precisely this group of patients that is more likely to be clinically recognized and to receive treatment for SDB. Moreover, studies that reported a high prevalence of SDB in presurgical patients were subject to significant selection bias because not all patients underwent polysomnography.^{1,53,54} In the largest single academic center registry study of presurgical patients undergoing anesthesia, Ramchandran et al²⁵ reported an SDB prevalence of 7% in 43,576 adults. Therefore, we believe that the NIS database does not represent a significant underreporting of clinically significant cases of SDB. Additionally, we demonstrate increasing prevalence of SDB with each successive year, as it has been shown in the past with nationwide surveys.^{13,55} Finally, we do not have clinical information on all potential confounders, such as BMI.

In summary, with the use of a large and nationally representative database, we report that SDB is independently associated with significant postoperative cardiopulmonary complications but not with in-hospital mortality, LOS, and total charges after elective surgery. Given the overall low rates of complications, prospective, large-scale, multicenter randomized controlled trials are needed to assess the impact of SDB treatment on patient outcomes during the postoperative period. Further research is needed to better elucidate the impact of SDB on postoperative mortality, particularly in certain high risk subgroups of SDB,

such as obesity hypoventilation syndrome, the overlap syndrome, or SDB accompanied by pulmonary hypertension.

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Dr Mokhlesi: contributed to the study concept and design, obtaining the funding, study supervision, data analysis and interpretation, statistical analysis, drafting of the manuscript, and critical revision of the manuscript for important intellectual content.

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