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SCIENTIFIC INVESTIGATIONS

Reduction in medical emergency team activation among postoperative surgical patients at risk for undiagnosed obstructive sleep apnea

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Study Objectives: Obstructive sleep apnea (OSA) is an under-recognized condition that results in morbidity and mortality. Postoperative complications, including medical emergency team activation (META), are disproportionally increased among surgical patients at risk for OSA. A systematic approach is needed to improve provider recognition and treatment, but protocols that demonstrate improvement in META are lacking. As part of a multidisciplinary quality improvement project, DOISNORE50 (DIS), a sleep apnea questionnaire and proactive safety measure, was algorithmically applied to all perioperative patients.

Methods: Consecutive sleep screening was conducted among perioperative patients. Of the 49,567 surgical navigation center patients, 11,932 had previous diagnosis of OSA. Of the 37,572 (96%) patients screened with DIS, 25,171 (66.9%) were Low Risk (DIS < 4), 9,211 (24.5%) were At Risk (DIS ≥ 4), and 3,190 (8.5%) were High Risk (DIS ≥ 6) for OSA, respectively. High Risk patients received same-day sleep consultation. On the day of surgery, patients with Known OSA, At Risk, and High Risk for OSA received an "OSA Precaution Band." An electronic chart reminder alerted admission providers to order postoperative continuous positive airway pressure (CPAP) machine and sleep consult for patients High Risk for OSA.

Results: Implementation of a comprehensive program was associated with increased sleep consultation, sleep testing, and inpatient CPAP use ($P < .001$). For every 1,000 surgical patients screened, 30 fewer META, including rapid responses, reintubation, code blues, and code strokes, were observed. However, inpatient sleep consultation and inpatient CPAP use were not independently associated with reduced META. In the subgroup of patients hospitalized longer than 3 days, inpatient CPAP use was independently associated with reduced META.

Conclusions: In this single-center, institution-wide, multidisciplinary-approach, quality improvement project, a comprehensive OSA screening process and treatment algorithm with appropriate postoperative inpatient CPAP therapy and inpatient sleep consultations was associated with increased CPAP use and reduced META. Further prospective studies are needed to assess cost, feasibility, and generalizability of these findings.

Keywords: EMR, electronic chart reminder, banner, sleep screen

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BRIEF SUMMARY

Current Knowledge/Study Rationale: Obstructive sleep apnea is an under-recognized condition that results in morbidity and mortality. Postoperative complications, including medical emergency team activation, are disproportionally increased among surgical patients at risk for obstructive sleep apnea. A systematic approach is needed to improve provider recognition and treatment, but protocols demonstrating improvement from medical emergency team activation are lacking. As part of a multidisciplinary quality improvement project, DOISNORE50, a sleep apnea questionnaire derived from medical emergency team activation, was introduced as an obstructive sleep apnea screening tool.

Study Impact: This study demonstrates that the sleep screening process and treatment algorithm with appropriate perioperative continuous positive airway pressure therapy and sleep consultations are associated with increased continuous positive airway pressure use and reduced medical emergency team activation among patients at risk for obstructive sleep apnea.

INTRODUCTION

Obstructive sleep apnea (OSA) is a common problem that often escapes diagnosis. It has been estimated that as many as 82% of men and 93% of women with OSA have not been diagnosed,[1,2] resulting in significant morbidity and mortality as well as significant health care costs annually.[3–11] Major hospital events and other postoperative complications disproportionately affect patients with OSA and are associated with increased length of stay, reintubation rates, atelectasis, pneumonia, and respiratory failure.[12–16] During preoperative visits, OSA is under-recognized by physicians, including surgeons and anesthesiologists.[4,5] A systematic approach to these patients is needed to improve provider recognition of OSA and thereby reduce medical emergency team activation (META) and other postoperative complications.[17–20]

Specialty societies and The Joint Commission have published guidelines and safety warnings that support perioperative sleep screening and management.[21] Yet, operationalizing OSA

Table 1—Sleep screening process and safety protocol.

Preoperative Screen
1. All patients complete prescreen questions (Do you have OSA? Are you on CPAP?) a. Yes to either question: patient identified as Known OSA b. No to both questions: patient screened with DIS and stratified as Low Risk, At Risk, High Risk 2. Patients with Known OSA, At Risk for OSA, or High Risk for OSA are entered into sleep registry 3. Electronic reminder active on patient's chart identifies OSA or risk of OSA status
Day of Surgery
4. Sleep Alert wristband placed on patient in preoperative holding 5. BPAs activated, and providers receive BPA recommendations upon admission a. Known OSA on CPAP: BPA to use home CPAP device b. Known OSA not on CPAP: BPA for sleep consultation c. At Risk: BPA for sleep consultation and for desaturations < 85% for 90 seconds d. High Risk: BPA for same-day sleep consult, CPAP recommendation, PAC provider receives message to consider sleep consultation/study
Postoperative Follow-up
6. Outpatient follow up or referral with sleep provider 7. Sleep study order for patients who agree to testing

Sleep screening process and safety protocol detailing preoperative screening, day of surgery alerts and best practice advisory, and postoperative follow-up. BPA = best practice advisory, CPAP = continuous positive airway pressure, DIS = DOISNORE50, OSA = obstructive sleep apnea, PAC = perioperative assessment clinic, SNC = surgical navigation center.

screening and prehabilitation can be resource-exhaustive, especially if all surgical patients are expected to be screened.[17] Additional management challenges include determining which screened patients truly require intervention and defining the necessary actions to keep patients with known or suspected OSA safe throughout the perioperative period. The coronavirus disease 2019 (COVID-19) pandemic has forced providers to use virtual visits and avoid in-facility testing when prevalence of COVID-19 is high.[22] Because of a likely high prevalence of patients with OSA and increased postoperative risk, we developed a multidisciplinary screening protocol with enhanced safety interventions and collection apiori outcome measures (postoperative META which included rapid response, code blue, code stroke and reintubation).

METHODS

Performed by nurse navigators and perioperative providers, the sleep screen process was initiated within the multidisciplinary surgical navigation center and perioperative assessment clinic at Wake Forest Baptist Hospital. We attempted to screen all surgical patients.

We conducted an interrupted time series analysis.[23] Historical controls: From February 2015 to December 2016, DOISNORE50 (DIS) screening (**Figure S1** in the supplemental material) was introduced among all patients brought to the surgical navigation center and perioperative assessment clinic. No planned or specific interventions were introduced. Questionnaire results were available to surgical navigation center and perioperative assessment clinic provider at the time of the patient's visit and usual care for suspected sleep apnea was defined by the practitioner. These included sleep consultation, sleep testing, and measured outcomes of META and positive airway pressure (PAP) utilization (defined as AutoPAP or home continuous PAP [CPAP] use).

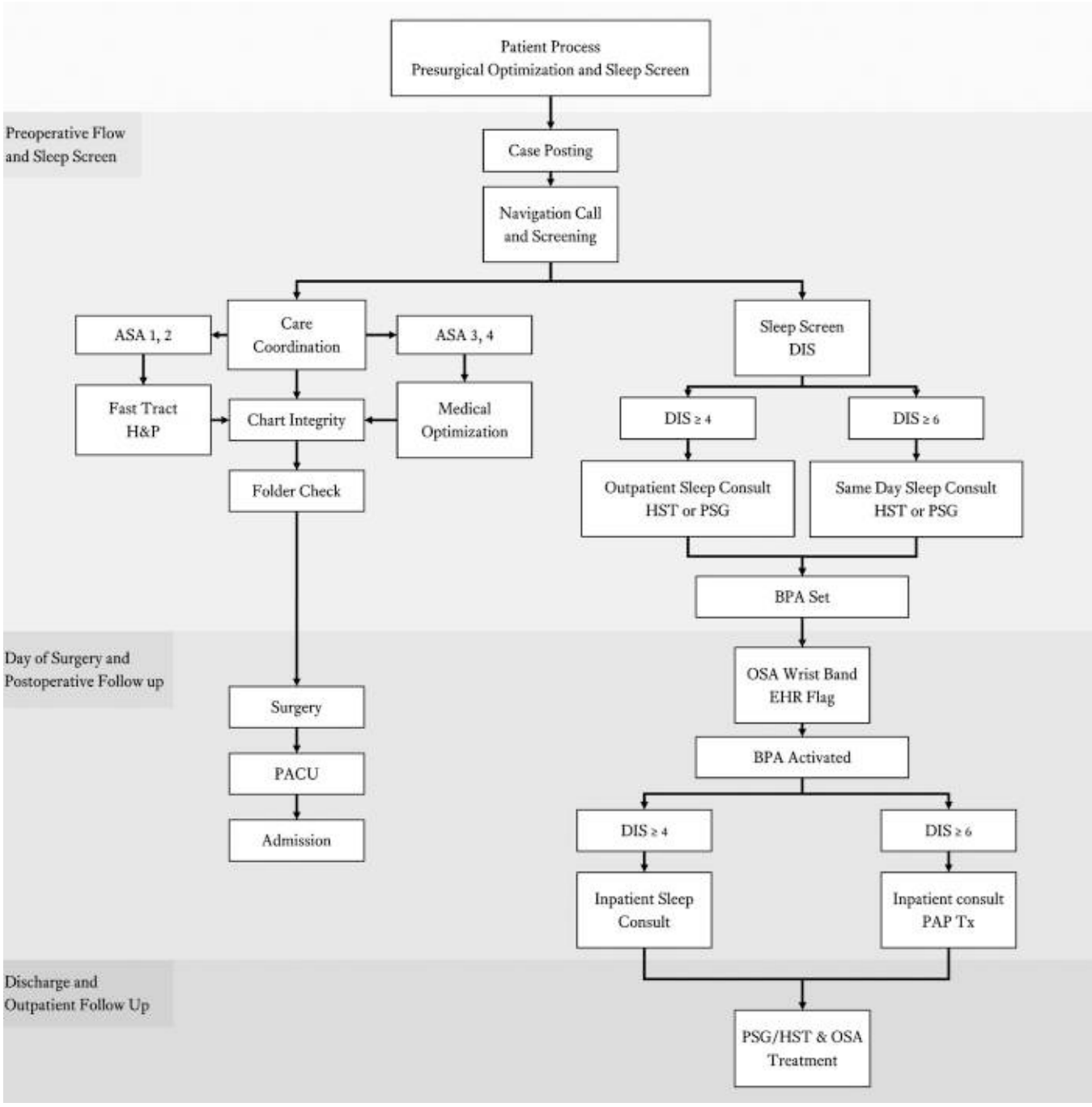
Quality and safety intervention

From January 2017 to December 2019, we introduced new tools to aid providers in initiating PAP therapy in combination with inpatient sleep consultation to enhance patient safety. Overall components of this program are outlined in **Table 1**, and the workflow in conjunction with surgical navigation center process is summarized in **Figure 1**.

Surgical navigator sleep screen algorithm and questionnaire development and validation

In February 2015, a mandatory sleep questionnaire, DIS, was added to the surgical navigation center and perioperative assessment clinic navigation screen after its performance as a patient-completed questionnaire for the risk of sleep apnea had been validated. Overall, questionnaire performance demonstrated a receiver operator characteristic (ROC) of 0.78 for patients at risk of OSA for the years 2017–2019 (**Figure S2** in the supplemental material) (Andrew M. Namen, MD, unpublished data, 2022). Completion of the questionnaire was required for each patient encounter either by telephone or face-to-face. Certain discrete elements—age, body mass index (BMI) within last 30 days, and sex—were extracted from existing data in the electronic medical record (EMR) and auto-completed the related questionnaire responses. If a condition or anthropometric measure was unknown, including BMI or neck circumference, during telehealth/phone consultation, a value of "no" was placed on the questionnaire. Patients were considered to have a diagnosed OSA if they answered yes to either prescreen question, "Do you have sleep apnea?" and/or "Do you use CPAP (continuous positive airway pressure) for OSA?" For those without a

Figure 1—DOISNORE50 workflow.



Workflow of DOISNORE50 screening in addition to surgical navigation center process. ASA =American Society of Anesthesiologist Physical Status Score, BPA = best practice advisory, DIS = DOISNORE50, EHR = electronic health record, H&P = history and physical, HST = home sleep test, OSA = obstructive sleep apnea, PACU, postanesthesia care unit, PAP = positive airway pressure, PSG = polysomnography, Tx = treatment.

known diagnosis of OSA, the DIS questionnaire was completed, and patients were deemed At Risk for OSA if they had positive responses to 4 or 5 of the questions. If they had 6 or more positive responses, they were considered High Risk for OSA. Patients with diagnosed OSA as well as those who screened At Risk or High Risk for OSA were automatically entered into an electronic sleep registry database.

Provider tools for sleep apnea screen algorithm adherence

Sleep apnea precautions band and best practice advisory

All patients with known or suspected OSA were included in the sleep registry and were flagged for sleep apnea precautions. A wristband (**Figure S3** in the supplemental material) was placed

on the patients in the holding room on the day of surgery. This visual aid cautioned providers of the patient's OSA status, understanding of which had been fostered by a system-wide precaution statement announcing the creation of sleep apnea best practice advisory that would alert providers to the availability of sleep consultation and monitoring, to consider the mitigation strategies of narcotics and sedatives for postoperative pain and anxiolytics, and to maintain head of bed greater than 30°—if clinically appropriate for the identified patient. All hospital providers were made aware of the recommended precautions through a health system statement and educational forums. An SBAR (situation, background, action, and recommendations) release was sent in a mass email campaign with a link to the more detailed statement that was continuously available for review. Quarterly meetings with the perioperative assessment clinic and postanesthesia care unit staff were conducted with a review of the process and question and answer/question forum.

Sleep registry and best practice advisory

A sleep registry in the EMR had been developed. It functioned as a data repository of all patients with both known OSA and At Risk status with predefined criteria of apnea-hypopnea index or respiratory event index ≥ 5 events/h and DIS ≥ 4. Additional functions of the registry included at least in part the development of clinical reporting, a platform from which best practice advisories were to be triggered and a data warehouse from which de-identified data could be obtained for research. The sleep registry required an electronic medical record. It took approximately 6 meetings with sleep faculty and information technology (IT) staff to create rules for entry into the registry as well as exclusions. All fields collected in the registry had discrete data elements for consistent reporting. Data originated from provider-entered entered the database via a sleep flowsheet. Data included DIS results, Epworth Sleepiness Scale scores, sleep study results from polysomnogram, PAP titration, home sleep testing, problem list, physical exam (neck circumference and BMI), social history, sleep related orders (PAP prescriptions), and sleep-related appointments, as well as patient response to treatment (acceptance or refusal of CPAP). Overall maintenance of the registry required yearly review of the integrity of the data.

A best practice advisory is an IT tool within the electronic medical record that is capable of crossing over different clinical environments. When sleep registry patients were admitted to the hospital, a best practice advisory with predefined orders for PAP and/or inpatient sleep consultation was triggered. This approach simplified the admitting providers' activity to 2 clicks of the computer mouse. By accepting both orders (preoperative anesthesiologist within the perioperative assessment clinic or admitting provider, ie, surgeon, etc), a sleep consultation request was sent to the sleep consultation service and the respiratory care team was notified of the need for PAP initiation. If the provider felt that the patient's clinical scenario was not appropriate for PAP and opted to decline these orders, they were prompted to provide an explanation. Predefined choices included patient refusal, "inappropriate for patient's postoperative care", physician refusal, and "other", which required a free text comment. These data were recorded in the registry and helped identify barriers to postoperative OSA management.

The best practice advisory was not limited to surgical admissions and would be triggered any time a sleep registry patient was being seen in the inpatient or outpatient setting within the health system. If a sleep study was completed and was negative for OSA, the patient was removed from the registry, and the best practice advisory no longer triggered.

Sleep screen and safety protocol

Known OSA on PAP

If both the preexisting diagnosis of OSA and/or use of PAP therapy were affirmed, the patient was advised to come to the hospital with their PAP device on the day of surgery. On patient admission, an automated best practice advisory and order was sent to the admitting provider for signature advising the respiratory therapist that "patient may use home PAP devices." These were evaluated by the respiratory therapist to assure proper device function. If the device was deemed unsatisfactory, the hospital provided a suitable device during the hospitalization. CPAP or AutoPAP use was documented in the respiratory "flowsheet" within the EMR and analyzed for nights of use and cross-referenced with charge data for hospital CPAP devices.

Known OSA, not on PAP therapy

For patients with known history of OSA who had refused PAP or failed PAP at home, providers were alerted to their OSA diagnosis and advised to offer PAP therapy during hospitalization and recommend consultation with a sleep provider (**Figure S4** in the supplemental material). If it were known that the patient was noncompliant with PAP prior to surgery, the preoperative physician had the option to consult a sleep specialist to optimize therapy prior to surgery.

At risk for OSA with American Society of Anesthesiologists physical status score 1 and 2

Patients received an initial American Society of Anesthesiologists (ASA) physical status score from the surgical team at the time of case posting (pre-ASA score). Per protocol, patients with a pre-ASA score of 1 or 2 received a preoperative evaluation by phone conducted by a surgical navigation center nurse. Per the approved protocol, all patients with a DIS ≥ 4 on this screen were referred to the outpatient sleep clinic for in-lab polysomnography or home sleep study (including either unattended peripheral arterial tonometry [WatchPat 200/300 or WP1; Itamar Medical, Inc, Franklin, MA] or ResMed ApneaLink Air [ResMed, San Diego, CA], based on their morbiddities, including but not limited to heart failure, chronic obstructive pulmonary disease, or stroke per Centers for Medicare & Medicaid Services/American Academy of Sleep Medicine guidelines.[24,25] A sleep provider review was completed following referral and confirmed the appropriate testing. A surgical packet was provided to the patient, which included a sleep apnea precaution band. On the day of surgery, the OSA precaution band was placed on the patient. If the patient was admitted, and significant hemoglobin oxygenation desaturations were

noted (85% saturations for > 90 seconds of undisturbed sleep), a provider evaluation was requested by nursing staff.

At risk for OSA with an ASA 3 and 4

While most ASA 3 and 4 patients were seen in the perioperative assessment clinic, those undergoing low risk surgery received a prescreen call from a nurse navigator. Patients with a DIS score ≥ 4 were entered automatically into the sleep registry with a recommendation that the preoperative provider make a referral for outpatient sleep consultation and recommended sleep study. The patients could opt to decline the referral.

High risk for OSA with an ASA 1 and 2

Nurse navigators in the surgical navigation center placed a sleep clinic referral in the EMR that was approved by an anesthesiologist for patients with a pre-ASA score of 1 or 2 who screened High Risk for OSA during their preoperative phone evaluation. As these patients were at high risk for OSA, although scheduled for an elective procedure, the referral requested an urgent appointment so that any necessary diagnostic testing could be obtained prior to surgery. However, the referral did not have to be completed prior to surgery, unless specifically required by the preoperative provider. During the perioperative assessment clinic visit, the patient's inclusion in the sleep registry prompted postoperative activation of the best practice advisory of each patient's OSA risk status with order entry capabilities automatically launched during the admission order encounter. The admitting provider was asked to either initiate an order for inpatient sleep consultation, AutoPAP therapy, or both. The provider had the option to decline these prompts but was required to provide justification (**Figure S4**).

High risk for OSA with an ASA 3 and 4

Patients with a pre-ASA physical status score of 3 or 4 were scheduled for a perioperative assessment clinic appointment prior to surgery. If the patient was High Risk for OSA based on the DIS, an immediate sleep consultation located within the perioperative assessment clinic was initiated. Prior to COVID-19, a dedicated sleep provider for preoperative sleep screening evaluated the patient, requested any necessary testing, and made patient-specific changes to the best practice advisory, ie, specific PAP settings, on an as-needed basis. If the patient was admitted, the best practice advisory alerted the admitting provider to the predefined PAP orders or suggested inpatient sleep consultation.

Medical emergency team activation

After a patient was discharged, independent reviewers who were blinded to the questionnaire responses collected data on rapid response calls and determined the incidence of a prior META. Data reviewed included Rapid Response paging system data cross-referenced with code team registry data. If the data existed on the code team registry but not on the rapid response pager, the data was entered for analysis. If the rapid response pager element was listed but not confirmed either in the chart or in the code team registry, the data was removed from analysis. These META included the need for rapid response, reintubation, code blue, code stroke, or death. Code blue alerts included cardiovascular or respiratory emergencies. Activation of the neurology team to evaluate sudden neurologic deterioration that might indicate cerebral vascular events defined as code stroke.

Statistical analysis

Descriptive statistics associating risk factors with sleep apnea and META were performed. Analysis of variance and chi-square and Fisher's exact tests were used for continuous and categorical predictors to determine which variables were associated with OSA (defined as an apnea-hypopnea index ≥ 5 events/h) and rapid response, reintubation, code blue, code stroke, and death, respectively. Questions that were unanswered were assumed as negative. We used logistic regression to determine the association between the sleep screen responses and META using patient's reported comorbidity, inpatient sleep consultation, inpatient CPAP use, and Charlson Comorbidity Index. All data were analyzed, and model fits validated using SAS 9.3 (SAS Institute, Inc, Cary, NC). We also conducted a likelihood ratio using age, sex, race, and BMI as continuous variables.

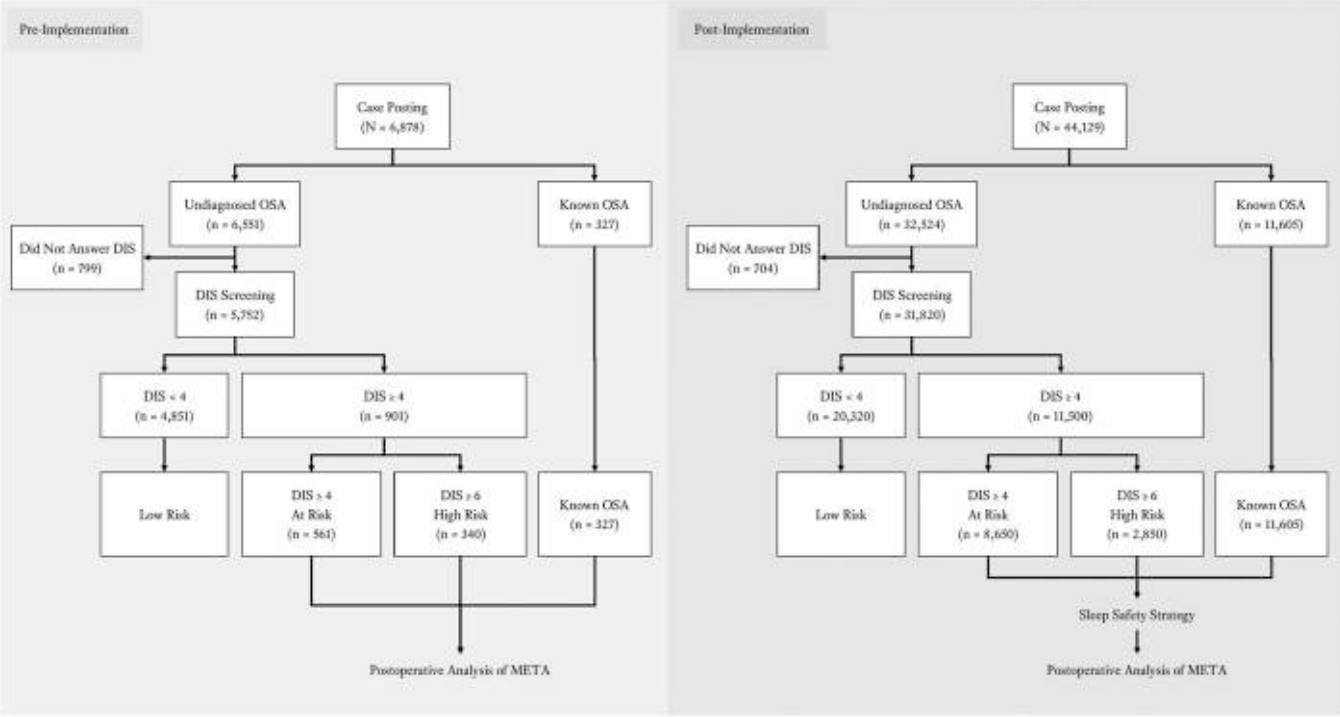
RESULTS

From January 2015 to December 2019, 51,007 cases were posted in the surgical navigation center and perioperative assessment clinic. Of those, 11,932 (24%) patients were noted to have previous diagnosis of OSA based on a self-reported questionnaire. Of the remaining 39,075 patients, 37,572 (96%) were screened with DIS, with 9,211 considered At Risk and 3,190 High Risk for OSA. Pre- (2015–2016) and post- (2017–2019) intervention consort diagram is provided in **Figure 2**. Demographic data demonstrated a male predominance and higher BMI when comparing Low Risk to High Risk patients (**Table 2**). Of the High Risk patients, 85% received a same day sleep consultation. Implementation of our intervention was confirmed by increases in the use of sleep consultations, sleep diagnostic and titration studies, and orders for and use of PAP (**Table 3**). Since same day sleep consult with perioperative assessment clinic and inpatient sleep consult did not previously occur prior to implementation, the change was significant. There was an increased regional anesthesia use among patients screened At Risk or High Risk in the implementation population (post) compared to observed (pre).

During this period, 2,021 medical emergency team activations occurred among patients who were screened. The relationship between META and preoperative risk of OSA as assessed through screening is summarized in **Table 4**. The risk for META increased with preoperative OSA risk: 4.8% Low Risk, 6.4% At Risk, and 7.1% High Risk for OSA. A higher proportion of code blue (from 1.2% to 2.4%, $P < .01$) and reintubations (1.3% to 1.8%, $P < .044$) occurred among patients at High Risk for OSA.

Logistic regression analysis was performed to adjust for covariates (**Table 5**). In addition, there was an increased regional anesthesia use among patients screened At Risk or High Risk in

Figure 2—CONSORT diagram for sleep screening process comparing pre (2015–2016) and post (2017–2019) implementation.



Patients were considered as Low Risk, At Risk, or High Risk for OSA based DIS scoring. CONSORT = Consolidated Standards of Reporting Trials, DIS = DOISNORE50, META = medical emergency team activation, OSA = obstructive sleep apnea.

the implementation population (post) compared to observed (pre) period. A statistically significant number of META were noted among At Risk (1.22, 95% confidence interval 1.09–1.36, P = .002) and High Risk (1.14, 95% confidence interval 1.06–1.24, P = .004) patients after controlling for covariates by logistic regression analysis. Logistic regression analysis of inpatient CPAP usage and inpatient consults was added to the above model and demonstrated that these covariates mitigated risk of META (**Table S1** and **Table S2** in the supplemental material). Two separate logistic regression models after controlling for all covariates demonstrated that neither the usage of CPAP nor inpatient consultation was statistically significant predictor of reduced META. Additional analysis in the subgroup of patients whose length of stay was > 3 days demonstrated that after adjusting for all covariates, inpatient CPAP use was significantly associated with reduced META (P < .001) (**Table 6**).

Interrupted time lapse series analysis comparing year of screen to time of screen and electronic chart reminders, sleep consultation, and AutoPAP intervention was conducted. A significant trend of increased PAP utilization was observed. CPAP charges were evaluated and confirmed a 4-fold rise compared to observation year (February 2015 to February 2016) (**Figure 3**). Also observed was a significant trend of reduced rapid response (23 fewer events per 1000 patients, P < .01), reduced code blue (3.5 per 1,000 patients, P < .033), and fewer intubations (2 per 1,000 patients, P < .049). No significant trend was identified among patients who sustained a code stroke.

Protocol adherence was further assessed. Evaluation of inpatient best practice advisory use by admitting provider team demonstrated 30% utilization either by completing an AutoPAP order or sleep consultation or both. Among High-Risk patients who had seen the sleep consultant, PAP orders were initiated 38% of the time, and overall META was 2%.

DISCUSSION

In an effort to improve patient safety and quality in the perioperative management of patients with known or suspected OSA based on the DIS questionnaire, a sleep apnea algorithm using electronic health records was adopted at Atrium Health Wake Forest Baptist. This strategic plan included a preoperative screening tool, a preoperative intervention with an expedited action plan, use of a comprehensive postoperative care plan with best practice advisory and action items for providers, and implementation of a closed loop care plan to enhance outpatient sleep care without delays in surgeries or mandating sleep testing prior to surgery.

We observed that patients At Risk and High Risk for OSA had a disproportionate risk of META compared to Low Risk patients. Additionally, we demonstrated that the use of electronic chart reminders and comprehensive and simplified order entry built within a best practice advisory assisted in the provider addressing patients' PAP needs with a 4-fold rise in

Table 2—Patient demographics and comorbidities.

	Low Risk			At Risk			High Risk			Known OSA		
	Pre	Post	*P*	Pre	Post	*P*	Pre	Post	*P*	Pre	Post	*P*
Total, n	4,851	20,320		561	8,650		340	2,850		327	11,605	
Age, median (IQR)	62.00 (50.00, 72.00)	64.00 (52.00, 73.00)	< .001	65.00 (57.00, 72.00)	65.00 (56.00, 72.00)	.102	62.00 (55.00, 70.00)	63.00 (56.00, 70.00)	.431	64.00 (54.00, 70.00)	64.00 (55.00, 71.00)	.172
Female, n (%)	2,652 (54.7%)	11,758 (57.9%)	< .001	204 (36.4%)	3,499 (40.5%)	.062	79 (23.2%)	846 (29.7%)	.016	147 (45.0%)	4,766 (41.1%)	.177
Race, n (%)			.141			.514			.292			.468
Caucasian	3,842 (79.2%)	16,303 (80.2%)		440 (78.4%)	6,890 (79.7%)		277 (81.5%)	2,234 (78.4%)		268 (82.0%)	9,444 (81.4%)	
African American	793 (16.3%)	3,090 (15.2%)		98 (17.5%)	1,480 (17.1%)		56 (16.5%)	521 (18.3%)		55 (16.8%)	1,902 (16.4%)	
Other	216 (4.5%)	927 (4.6%)		23 (4.1%)	280 (3.2%)		7 (2.1%)	95 (3.3%)		4 (1.2%)	259 (2.2%)	
BMI, median (IQR)	29.84 (25.52, 34.40)	29.86 (25.63, 34.40)	.742	32.09 (27.41, 35.29)	34.40 (30.11, 37.86)	< .001	34.40 (32.17, 37.94)	34.40 (32.89, 38.01)	.23	34.40 (31.21, 39.89)	34.40 (31.26, 39.14)	.484
LOS, median (IQR)	3.24 (2.12, 5.60)	3.10 (1.91, 5.25)	< .001	3.73 (2.21, 6.21)	3.12 (1.92, 5.32)	< .001	3.36 (2.19, 5.55)	3.21 (2.02, 5.65)	.076	3.32 (2.05, 6.42)	3.08 (1.90, 5.21)	.001
Current smoker, n (%)	1,265 (26.1%)	5,384 (26.4%)	.564	158 (28.1%)	2,008 (23.2%)	.009	99 (29.1%)	830 (29.1%)	.959	66 (20.1%)	1,059 (9.12%)	< .001
Type of surgery, n (%)			< .001			< .001			< .001			.008
General	722 (14.9%)	2,338 (11.5%)		67 (11.9%)	855 (9.9%)		44 (12.9%)	238 (8.4%)		39 (11.9%)	1,238 (10.7%)	
Cardiothoracic	313 (6.5%)	861 (4.2%)		45 (8.0%)	487 (5.6%)		39 (11.5%)	158 (5.5%)		21 (6.4%)	573 (4.9%)	
Neurosurgery	416 (8.6%)	1,524 (7.5%)		60 (10.7%)	669 (7.7%)		42 (12.4%)	167 (5.9%)		34 (10.4%)	835 (7.2%)	
Orthopedics	858 (17.7%)	4,542 (22.4%)		71 (12.7%)	1,827 (21.1%)		31 (9.1%)	530 (18.6%)		57 (17.4%)	2,545 (21.9%)	
Urology	518 (10.7%)	1,995 (9.8%)		65 (11.6%)	1,022 (11.8%)		43 (12.6%)	295 (10.4%)		36 (11.0%)	1,328 (11.4%)	
Cardiology	20 (0.4%)	352 (1.7%)		4 (0.7%)	222 (2.6%)		1 (0.3%)	90 (3.2%)		0 (0.0%)	279 (2.4%)	
Other	2,004 (41.3%)	8,708 (42.9%)		249 (44.4%)	3,568 (41.2%)		140 (41.2%)	1,372 (48.1%)		140 (42.8%)	4,807 (41.4%)	
Regional anesthesia, n (%)	2,291 (47.2%)	10,435 (51.4%)	< .001	267 (47.6%)	4,565 (52.8%)	.019	151 (44.4%)	1,445 (50.7%)	.033	170 (52.0%)	6,134 (52.9%)	.799
Inpatient CPAP, n (%)	634 (13.1%)	1,648(8.1%)	< .001	60 (10.7%)	3,155 (36.4%)	< .001	62 (18.2%)	982 (34.4%)	< .001	160 (48.9%)	5,510 (47.5)	.232

(continued on following page)

Table 2—Patient demographics and comorbidities. (*Continued*)

	Low Risk			At Risk			High Risk			Known OSA		
	Pre	**Post**	***P***	**Pre**	**Post**	***P***	**Pre**	**Post**	***P***	**Pre**	**Post**	***P***
Inpatient consults, n (%)	0 (0%)	125 (0.6%)	< .001	0 (0%)	213 (2.5%)	< .001	0 (0%)	426 (14.9%)	< .001	0 (0%)	408 (3.5%)	< .001
Comorbidity n, (%)												
Hypercapnia	157 (3.2%)	488 (2.4%)	.001	23 (4.1%)	291 (3.4%)	.418	19 (5.6%)	120 (4.2%)	.3	9 (2.8%)	396 (3.4%)	.3
AIDS	16 (0.3%)	57 (0.3%)	.671	3 (0.5%)	24 (0.3%)	.491	0 (0%)	4 (0.1%)	1	2 (0.6%)	21 (0.2%)	1
CHF	634 (13.1%)	2,048 (10.1%)	< .001	100 (17.8%)	1,460 (16.9%)	.602	86 (25.3%)	542 (19%)	.007	62 (19%)	2,117 (18.2%)	.007
Pulmonary disease	1,084 (22.3%)	3,915 (19.3%)	< .001	148 (26.4%)	2,261 (26.1%)	.938	85 (25%)	747 (26.2%)	.678	120 (36.7%)	3,161 (27.2%)	.678
DM	835 (17.2%)	2,726 (13.4%)	< .001	136 (24.2%)	1,999 (23.1%)	.572	106 (31.2%)	693 (24.3%)	.007	97 (29.7%)	2,825 (24.3%)	.007
Tumor malignancy	420 (8.7%)	1,457 (7.2%)	< .001	49 (8.7%)	400 (4.6%)	< .001	28 (8.2%)	120 (4.2%)	.001	13 (4%)	464 (4%)	.001
Liver disorder	71 (1.5%)	351 (1.7%)	.221	17 (3%)	160 (1.8%)	.069	9 (2.6%)	59 (2.1%)	.619	5 (1.5%)	173 (1.5%)	.619
MI	374 (7.7%)	1,259 (6.2%)	< .001	76 (13.5%)	814 (9.4%)	.002	54 (15.9%)	314 (11%)	.01	23 (7%)	1,087 (9.4%)	.01
Rheumatic	148 (3.1%)	534 (2.6%)	.114	14 (2.5%)	237 (2.7%)	.833	6 (1.8%)	62 (2.2%)	.766	7 (2.1%)	327 (2.8%)	.766
CCI, median (IQR)	2.00 (1.00, 4.00)	2.50 (1.00, 4.00)	.691	3.00 (2.00, 4.00)	3.00 (2.00, 4.00)	.002	3.00 (2.00, 4.00)	3.00 (2.00, 4.00)	.094	3.00 (2.00, 4.00)	3.00 (2.00, 4.00)	.277

Patient demographics, types of surgery and anesthesia, and comorbidities including Charlson Comorbidity Index for pre- and postintervention. AIDS = acquired immunodeficiency syndrome, BMI = body mass index, CCI = Charlson Comorbidity Index, CHF = congestive heart failure, CPAP = continuous positive airway pressure, DM = diabetes mellitus, IQR = interquartile range, LOS = length of stay, MI = myocardial infarction, OSA = obstructive sleep apnea.

Table 3—Sleep screen protocol impact.

Measurement	Pre-Protocol	Post-Protocol	*P*
Inpatient CPAP utilization, n	916	11,295	< .001
Inpatient sleep consult, n	0	1,172	< .001
Sleep lab appointment, n per month	271	301	.002

Analysis shows increased number of inpatient CPAP utilization, inpatient sleep consult, and sleep lab appointment (including home sleep testing and in-lab diagnostic and in-lab pap titration studies) after implementation of sleep screen protocol. CPAP = continuous positive airway pressure.

hospital CPAP initiation. Our study showed that a sleep screen protocol incorporating inpatient same day preoperative and inpatient sleep consultation and AutoPAP therapy for At Risk patients was associated with reduced rapid response, code blue, and reintubations among surgical patients. Additionally, inpatient CPAP use and inpatient sleep consult showed a nonsignificant trend toward reduced META. These findings suggest that reduced META was associated with our comprehensive quality improvement project, rather than individual components of the program.

Several caveats regarding our process underscore its feasibility and ease of portability and merit additional comment.

Preoperative screening tool

To minimize the time to complete the DIS questionnaire, automation was used, as in other studies, to prepopulate certain discrete elements within the screen, such as age, BMI, and sex.[26] Out of concern for adherence to screening steps, we included a feature to ensure that providers were not able to circumvent questionnaire completion. A "hard stop" function ensured compliance, with 96% of patients screened. Previous studies have demonstrated the utility of preoperative screening and have suggested measures necessary to encourage compliance (~74%), eg, the use of laminated cards and other multistep EMR approaches. The use of hard stop and autopopulation functions within a screening tool provided the needed IT builds to achieve more consistent application of sleep apnea screening as demonstrated in this application.[26,27]

Preoperative communication with intervention and expedited action plan

Historically, there have been barriers from the time of recommendation for sleep referral to completion of sleep evaluation and polysomnogram.[28] Current national trends outline that the timeline for being evaluated by a certified sleep specialist is prolonged. Major challenges to sleep apnea recognition and management include provider and patient education and communication. Knowledge gaps and lack of understanding lead to refusal of sleep consultation, referral, and testing. Therefore, a mechanism to improve patient and provider communication and education is imperative.

Our process of caring for patients involved 4 different mechanisms to enhance preoperative communication: same day consult with a sleep specialist (both preoperative and inpatient), an OSA precautions band, best practice advisory within the EMR, and a system-wide OSA precaution statement. Best practice advisories have been used for multiple other conditions with favorable results in both improved compliance with testing and treatment recommendations.[29–31] Unique to our study, the sleep consultant had the ability to modify the preoperative best

Table 4—Frequency of META vs risk for OSA.

	Low Risk			At Risk			High Risk			Known OSA/CPAP		
META	Pre	Post	*P*	Pre	Post	*P*	Pre	Post	*P*	Pre	Post	*P*
Total, n	4,851	20,032		561	8,650		340	2,850		327	11,605	
RRT, n (%)	201 (4.1%)	493 (2.4%)	< .01	37 (6.6%)	233 (2.7%)	< .001	20 (5.9%)	51 (1.8%)	< .001	15 (4.6%)	316 (2.7%)	< .001
CB/CS, n (%)	46 (0.9%)	274 (1.3%)	.082	13 (2.3%)	158 (1.97%)	.423	10 (2.94%)	68 (2.38%)	.042	8 (2.4%)	119 (1.02%)	.008
RI, n (%)	77 (1.6%)	253 (1.1%)	.07	12 (2.1%)	140 (1.6%)	.443	5 (1.5%)	42 (1.47%)	.803	4 (1.2%)	143 (1.2%)	.803
META, n (%)	324 (6.7%)	1020 (6.1%)	.061	62 (11.1%)	531 (6.1%)	< .001	26 (7.6%)	160 (5.5%)	.010	21 (6.4%)	490 (4.2%)	.571

Frequency of META increased among "At Risk" and "High Risk" patients in comparison with "Low Risk" patients. Frequency of META was reduced within all groups between pre and post. CB = code blue, CPAP = continuous positive airway pressure, CS = code stroke, META = medical emergency team activation, OSA = obstructive sleep apnea, RI = reintubation, RRT = rapid response team.

Table 5—Logistic regression model for META based on post-implementation data.

	OR (95% CI)	*P*
Female	0.752 (0.672, 1.022)	.726
Race (reference = Caucasian)		
Caucasian	0.831 (0.764, 1.282)	.892
African American	1.142 (0.766, 1.312)	.651
Age	1.01 (0.644, 1.022)	.244
BMI	0.874 (0.991, 1.022)	.062
LOS	1.022 (0.988, 1.143)	.582
Type of surgery		
General (reference = Other)	1.066 (0.954, 1.199)	.326
Cardiothoracic (reference = Other)	1.274 (0.928, 1.614)	.068
Neurosurgery (reference = Other)	0.851 (0.552, 1.018)	.644
Orthopedics (reference = Other)	0.832 (0.488, 1.032)	.691
Urology (reference = Other)	0.899 (0.879, 1.159)	.436
Cardiology (reference = Other)	1.014 (0.828, 1.266)	.854
Regional anesthesia	1.178 (0.855, 1.475)	.0761
Current smoker	0.752 (0.962, 1.054)	.062
CCI	1.186 (0.921, 1.354)	.071
DOISNORE50 scoring (reference = Low Risk)		
At Risk	1.221 (1.092, 1.362)	.002*
High Risk	1.142 (1.066, 1.248)	.004*
Known OSA	1.088 (0.959, 1.232)	.079

Logistic regression analysis showing At Risk and High Risk patients having increased risks for META after adjustment for covariates. Low Risk, At Risk, or High Risk for OSA are defined by DOISNORE50 < 4, ≥ 4 and < 6, and ≥ 6, respectively. *Statistically significant. BMI = body mass index, CCI = Charlson Comorbidity Index, CI = confidence interval, LOS = length of stay, META = medical emergency team activation, OR = odds ratio, OSA = obstructive sleep apnea.

practice advisory, which became active during the postoperative care and availed the provider specific treatment orders without additional effort.[32,33] There was a seamless interaction between the best practice advisory and the registry. Based on predefined rules, the best practice advisory was triggered for several key populations within the registry: diagnosed OSA patients on treatment, a recent diagnosis of OSA not yet on treatment, and those who screened at risk or high risk with the DIS. Best practice advisories provided a quick and easy platform for providers to order PAP therapy and inpatient sleep consultation. This IT build encouraged patient and provider interaction for PAP intervention postoperatively. Overall, the 30% adherence was associated with a 4-fold rise in PAP utilization among surgical patients at risk.

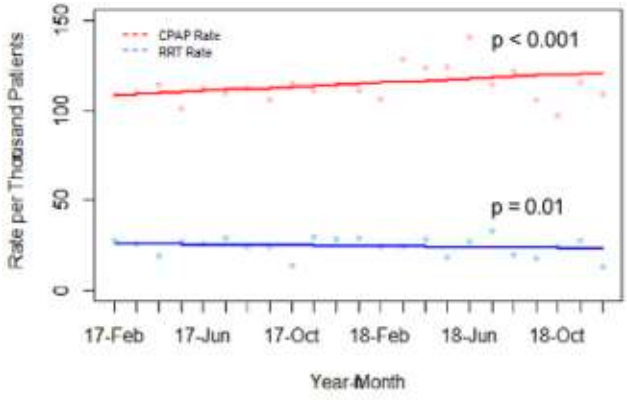
Since polysomnography was not an essential feature of our program prior to surgery, there was a concern that diagnoses would be forsaken. However, the sleep consultant and communication technologies likely offset this possibility postoperatively as seen by the increase in outpatient sleep clinic appointments and polysomnograms (**Table 3**). It was the sleep consultant's responsibility

Table 6—Logistic regression model to explore the independent association of inpatient CPAP use and META based on hospital length of stay.

	n	OR (95% CI)	*P*
Post-implementation	43,137	0.859 (0.589–1.037)	.168
Post-implementation, LOS ≥ 1 day	39,132	0.869 (0.601–1.032)	.121
Post-implementation, LOS ≥ 2 day	27,821	0.872 (0.505–1.028)	.105
Post-implementation, LOS ≥ 3 day	18,669	0.881 (0.552–0.924)	< .001*

Odds of META on CPAP usage after controlling for all other covariates among patients whose length of stay is > 3 days. *Statistically significant. CI = confidence interval, CPAP = continuous positive airway pressure, LOS = length of stay, META = medical emergency team activation, OR = odds ratio.

Figure 3—Interrupted time lapse series analysis (above) and frequency of META in patients at risk for sleep apnea (below).



META	Reduction from Sleep Screen Protocol, per 1000 patients	Number Needed to Screen to reduce one META
RRT	23	43
CB	3.5	286
RI	2	500
CS	2	500
Total	30.5	33

Sleep screen protocol and AutoPAP initiative is associated with 4-fold rise in CPAP initiation and 30 fewer META per 1000 hospitalized patients. CB = code blue, CPAP = continuous positive airway pressure, CS = code stroke, META = medical emergency team activation, PAP = positive airway pressure, RI = reintubation, RRT = rapid response team.

to ensure the needed postoperative patient care, such as response to PAP, as well as other essential sleep-related communication and sleep-study and sleep-clinic appointments. Another aid to communication, the sleep apnea alert band, served as a visual cue and functioned as a constant reminder regarding the potential risk of OSA and implied the concern for the use of respiratory depressants.

A comprehensive postoperative care plan and improved outpatient management

In order to implement a comprehensive perioperative care plan, early identification and recognition of OSA status is key. Often patients leave a health system temporarily only to return needing immediate surgery. Inclusion in the sleep registry helped to ensure that a patient's OSA status was not only present in the immediate postoperative period but also during the longitudinal journey through a health system (including other admissions or during outpatient clinic visits). The Atrium Health Wake Forest Sleep Registry comprised patients with a known or suspected diagnosis of OSA. Once patients had a confirmed negative sleep study, they were removed from the registry. The registry therefore contained those individuals in whom the burden of OSA could be identified. The data in the sleep registry could be accessed for patient care and research and serve to expedite appropriate care through best practice advisory initiation (both surgical and nonsurgical admissions) and enhanced outpatient management (**Table 3**), ie, sleep consultation, especially among those who screened positive but failed to have a consultation or their sleep tested. From clinical reports offered by the sleep registry, health systems can intervene and close the loop on OSA care. Furthermore, analyzing registry data can determine other risk factors and provide the basis for additional research in order to mitigate OSA-related META.

Our experience demonstrated an increase in PAP therapy over time. Previous trials have shown mixed results regarding postoperative and perioperative PAP therapy and their outcomes among select surgical known OSA patients.[32–34] One multisite, retrospective study did not demonstrate a significant improvement following PAP initiation.[35] Other prospectively designed studies demonstrated benefits from PAP with reduced rates for reintubation and postoperative atelectasis/pneumonia observed among bariatric and abdominal surgical patients.[36] Postoperative PAP application has also been associated with reduced postoperative atrial fibrillation, especially among cardiovascular surgical patients.[37,38] Based on time lapse series analysis of this cohort, CPAP was associated with reduced META. Although the logistic regression analysis demonstrated a lack of association between inpatient CPAP use or inpatient sleep consultation and META, there was a trend toward reduced META (**Table S1** and **Table S2** in the supplemental material). These findings support the notion that that a comprehensive multidisciplinary approach is needed to achieve the benefit of reduced META, including but not limited to systematic screening for OSA, best practice advisory utilization, CPAP usage, and inpatient consult. Further subgroup analysis did demonstrate that patients who were on CPAP and who had a length of stay > 3 days or longer were associated with reduced META (**Table 6**). Additional analyses are needed to identify factors that have greater weight on the improved outcomes.

Implementation of OSA screening in the surgical navigation center and perioperative assessment clinic and the postoperative tools and action plan enhanced a culture of safety for known and suspected OSA at our center. However, several limitations of our initiative must be acknowledged. Importantly, our use of interrupted time lapse series analysis did not allow for specific cause and effect determinants: We are uncertain whether PAP utilization alone was the cause of reduced META.

Additionally, the influence of the action items on provider behaviors regarding changes to anesthesia plans was not measured by survey or other instrument; this includes the details of postoperative sedatives or opioid. However, an increase in regional anesthesia was noted among patients At Risk and High Risk vs Low Risk in the post-implementation period. The individual components of our intervention were assessed, including sleep screen and same day sleep consultant adherence in the perioperative assessment clinic, sleep consultant influence on

META, and best practice advisory and PAP utilization, the potential influences on reduced META. The summation of the action items independently and not the separate components demonstrated benefit and supports the hypothesis that the combination of the aforementioned action items led to reduced META.

The aims of this undertaking were to influence providers and their behavior to commit to a culture of sleep apnea safety. We did not assess prospectively their perceptions of the alerts, best practice advisories, or orders to see if the patient's sleep apnea status was affected by their surgical or anesthesia plan. Future studies and surveys are needed.

It is noteworthy that our algorithm did not require polysomnography for definitive confirmation of OSA. We believe that such objective diagnostic testing is highly desirable but an impractical absolute requirement for all patients because of several factors. These include the high prevalence of OSA in positively screened patients, financial cost of testing, and potential time constraints with delays in needed surgeries and patient perceptions regarding sleep apnea.[39]

External unmeasured influences could have affected our observations, particularly as this study design assessed an infrequent event, META, in a large cohort over a 4-year period. We were reassured by logistic regression analysis of the independent influence of OSA on META, using validated models. However, this does not exclude other potential elements.

The proposed model of care for a health system requires a well-integrated EMR with the aforementioned capabilities. However, the development and the maintenance of a sleep registry, EMR tools, and other IT builds require continuous IT resources, an upfront cost that may create barriers to development. A fragmented model or inconsistent support will likely limit success. However, in order to avoid the human and financial cost of META, perioperative sleep screening and inpatient support should not waiver.

Our study was not designed to assess cost-effectiveness of our intervention. Moreover, the feasibility of implementing our systematic OSA screen and treatment algorithm at other institutions remains unknown. As such, caution must be exercised regarding the generalizability of our findings.

With the advent of COVID-19 and the newly imposed restrictions placed on sleep testing and the heightened need for timely surgery, this approach offers health systems an alternative to favorable outcomes and merits further evaluation.

The retrospective and uncontrolled nature of this study is prone to inherent bias and limitations, and the use of validated Charlson Comorbidity was used. Other risk measures and comorbidities could have been considered. In a large cohort study of this design, events outside of admission and hospitalization were not collected or analyzed. In addition, although we had cross-referenced 2 sources of well collected data, observed META may have been missed and potentially underrepresented. Further prospective investigation is needed.

Despite these and other limitations, this algorithm for OSA screening and postoperative care is feasible and provides a closed loop model for diagnosis and treatment of patients at risk of sleep-related hospital events due to known or suspected OSA. Moreover, the impact of this loop closure is best exemplified by noting that a screen occurring in the preoperative period of one surgical encounter can act as a catalyst for several subsequent interactions that together work to improve OSA management in longitudinal care.[40] This dynamic process continues to be tested, analyzed, and changed in order to improve the safety of postoperative patients with OSA and identify undiagnosed OSA patients in time to improve their care.

ABBREVIATIONS

ASA, American Society of Anesthesiologists
BMI, body mass index
CPAP, continuous positive airway pressure
DIS, DOISNORE50
EMR, electronic medical record
IT, information technology
META, medical emergency team activation
OSA, obstructive sleep apnea
PAP, positive airway pressure

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DISCLOSURE STATEMENT

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