Predictors of At-Home Arterial Oxygen Desaturation Events in Ambulatory Surgical Patients

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Objectives: Little is known about the early recovery phase occurring at-home after anesthesia and surgery in ambulatory surgical patients. We studied quantitative oximetry and quality-of-life metrics in the first 48 hours after same-day orthopedic surgery examining the association between the recovery metrics and specific patient and procedural factors.

Methods: We used the STOP-Bang score to quantify patient risk for obstructive sleep apnea in 50 adult patients at 2 centers using continuous portable oximetry and patient journaling. Parametric statistical procedures were used to assess relationships among patient and procedural factors and desaturation events.

Results: Higher STOP-Bang scores were predictive of the number and duration of desaturation events below mild and severe thresholds for arterial oxygen saturation during their first 48 hours after discharge from ambulatory surgery. Older patients and patients with higher BMI in particular were at an increased risk of mild and severe arterial oxygen desaturation. Using a home CPAP reduced the number of desaturation events. Of interest, taking opiate analgesics decreased the number of desaturation events.

Conclusions: Given the absence of systematic research of early ambulatory anesthesia/surgery recovery at home and concerns of postoperative respiratory events, our results have clear implications for patient safety. Our results imply that screening based on noninvasive STOP-Bang scores may allow for suggestions for recovery from ambulatory surgery, such as encouraging patients with high scores to use home CPAP and aggressive education regarding use of opiates.

Key Words: ambulatory surgery, arterial desaturation events, obstructive sleep apnea, oximetry, patient safety, postoperative complications

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Little is known about the early recovery phase occurring at-home after anesthesia and surgery in ambulatory surgical patients. Concerns associated with adverse respiratory events (sometimes lethal) led to the establishment by the Society of Anesthesia and Sleep Medicine and the Anesthesia Closed Claims Project of an "Obstructive Sleep Apnea Death and Near Miss Registry," the goals being to identify the level of monitoring involved at the time of death or near-miss, describe why the adverse event occurred, and provide insight on how best to study the phenomena.[1]

In a 2015 closed claims analysis involving patients hospitalized after surgery, 88% of the respiratory depression events occurred within 24 hours of surgery, with 77% of these resulting in severe brain damage.[2] Not included in that analysis are a number of lethal respiratory events occurring in children after tonsillectomy.[3] Recent editorials echo concerns about postoperative respiratory events in those with obstructive sleep apnea (OSA) in the aftermath of anesthesia and surgery, one calling it "the elephant in the room," another using the sobering epithet "dead-in-bed."[4–6] Although outpatients, in general, may have a reduced risk for respiratory depression and low levels of arterial oxygen saturation (SpO_2), the minimal monitoring available for these patients, once discharged from the ambulatory facility, makes any respiratory depression event potentially catastrophic.

In this study, our aim was to track outpatients' respiratory and quality-of-life metrics in the first 48 hours after discharge after orthopedic surgery. We then examined the association between the recovery metrics and specific patient and procedural factors. We used the STOP-Bang score to quantify patient risk for OSA.[7–9] We believe this is a first-of-its-kind study.

There are approximately 6 million surgeries performed in ambulatory centers annually; therefore, the current study is relevant to the domain of patient safety as surgery in this setting is anticipated to grow.[10] Further motivating our inquiry is the increase in domestic opiate-related deaths, the frequent failure of clinicians to engage in patient-centric opiate prescribing, and poor compliance by patient users.[11]

We addressed the following hypotheses relative to the first 48 hours in-home after discharge from ambulatory surgery:

1) The STOP-Bang score predicts SpO_2 desaturation events in the postoperative period.
2) There are specific elements of the STOP-Bang score that predict desaturation.
3) There are specific quality of life metrics recorded in a patient-managed journal that predict desaturation events.

MATERIALS AND METHODS

Study Design

Institutional review board approval was obtained from Virginia Commonwealth University Medical Center in Richmond, Virginia, and Great River Medical Center in West Burlington, Iowa.

During their presurgical visit, we obtained informed consent and explained how to fill out the journal and use the oximeter. This prospective study gathered quality-of-life information obtained through patient journaling and respiratory factors quantified by pulse oximetry. Data obtained from the preanesthesia history and physical, including body mass index (BMI), sex, surgical intervention, anesthesia technique, STOP-Bang score, and comorbidities, were recorded. At discharge, each patient was presented with a journal and a calibrated wristwatch-sized oximeter with fresh batteries. After the second postoperative night and completion of the study protocol, participants returned the journal and oximeter to the research team in a postage-paid, addressed envelope for data extraction and entry. Journal information was entered

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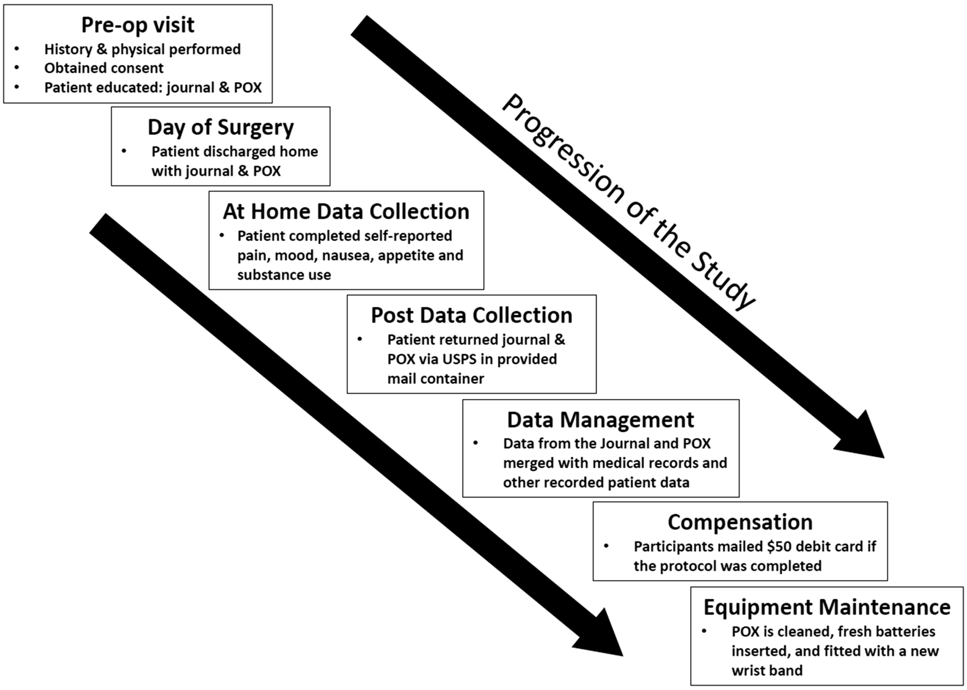

FIGURE 1. Timeline for individual participants.

into a spreadsheet with preanesthesia history and physical data, and pulse oximetry data were extracted from each device using the proprietary software package. Patients who completed protocol were given a $50.00 debit card. The study chronology is presented in Figure 1.

Study Subjects

Patients were included if they were 18 years or older and were candidates for same-day discharge after orthopedic surgery. Secondary criteria included the ability to read and write, perform journal entries, and comply with the pulse oximeter protocol. Individuals were excluded from the study if they were pregnant, incarcerated, or admitted for overnight stay. Based on an a priori power analysis, 50 subjects were included in the analysis. Fifty-three patients met the inclusion criteria. Three were excluded, 2 because of oximeter battery failure and 1 because of not completing all journal entries.

Instruments

Medical History and Physical Data

All participants received a preanesthesia history and physical. This included age, sex, height, weight, STOP-Bang score, surgical and medical history, organ system assessment, current medications and supplements, drug allergies, ASA physical status classification, anesthetic technique, surgical procedure, use of a continuous positive airway pressure device (CPAP), and laboratory results.

Although polysomnography remains the definitive tool for establishing a diagnosis of OSA, the STOP-Bang score is accepted to establish the risk/presence of OSA and is commonly used nationwide as part of the preoperative anesthetic assessment.[7–9] There are 8 elements of the STOP-Bang tool (Table 1). Generally, the STOP-Bang is used to stratify participants into 2 major categories: those with probable OSA as indicated by answering yes to 3 or more items, and those without OSA as indicated by answering yes to

TABLE 1. STOP-Bang Inventory With the Frequency of Endorsement in the Sample

	Item	Yes	No
STOP	**S**noring: Do you snore loudly?	34	16
	Tired: Do you often feel tired or sleepy?	24	26
	Observed: Has anyone observed you stop breathing during your sleep?	43	7
	Blood **p**ressure: Do you have high blood pressure?	27	23
Bang	**B**ody mass index >35 kg/m^2?	23	27
	Age older than 50 years?‡	26	24
	Neck circumference >16 inches?	24	26
	Sex: male?	29	21

High risk for obstructive sleep apnea = answering “Yes” to 3 or more items.

‡For age, the mean is 50.4 years with a standard deviation of 11.2 years.

fewer items. We quantified the unique elements measured in each patient for later analysis.

Patient Journal Data

The journal (see Supplemental Digital Content 1, http://links.lww.com/JPS/A46) comprised self-reports of mood, pain, nausea, alcohol and tobacco use, and appetite. Activity and perceptions of sleep duration and quality, pain rating and use of analgesics, nausea, and treatment measures were also recorded. Patients completed journal-prompted entries for the entire 48-hour study period. Mood states were measured using single word adjectives (happy, sad, angry). Sleep duration was measured by the total number of minutes slept in the 48-hour period.

Pulse Oximeter Data

Participants wore a portable oximeter during periods of napping and sleep for the full 48 hours. The Respironics NONIN WristOx2 Model 3150 (Nonin Medical, Inc. Plymouth, Minnesota) is a Food and Drug Administration–approved device designed for portability and in-home use. It measures heart rate and arterial oxygen saturation (SpO_2). It is wrist mounted, like a watch, with a soft probe capped over a fingertip. It has a reported sensitivity and negative likelihood ratio of 100% and 0%, respectively, and a specificity of 100%.[12–14] Accuracy is reported to be 70% to 100% SpO_2 ± 2% SD and +3% for pulse rate, with a bias of +0.03 and precision of ±2.08 SD.[15] The device powers on when worn and is capable of continuously recording and archiving 72 hours of data.

Two separate thresholds of desaturation risk (SpO_2 level of 90% and 88%) were used to derive the total number of desaturation events and the total length of time spent below the specified SpO_2 threshold. This resulted in 4 variables: the number of SpO_2 events less than 90%, the number of SpO_2 events less than 88%, the total duration a patient's SpO_2 level less than 90%, and the total duration a patient's SpO_2 level less than 88%. Although this may seem like a seemingly small change in hemoglobin saturation with oxygen, small changes below 90% saturation results in a dramatic decrease in arterial oxygen pressure. Therefore, we defined the 2 SpO_2 thresholds to differentiate mild from more severe hypoxemia.

Data Analysis

Negative binomial regression methods were used to analyze the event count data. The duration of time with a SpO_2 level below 90% or 88% was also not normally distributed; however, a $\log_{10}$ transformation of these times was approximately normally distributed, and least squares regression was used to analyze this variable. The correlation between the number and duration of SpO_2 desaturation events at the 90% threshold was $r = 0.70$ (CI, 0.52–0.82) and at the 88% threshold was $r = 0.60$ (CI, 0.39–0.75).

RESULTS

Participants had a mean age of 50 years (SD = 11) and a mean STOP-Bang score of 3.4 (SD = 2.1). Table 1 displays the range of STOP-Bang assessments by individual element, and Table 2 displays patient demographics.

To address our first hypothesis, we examined 4 models testing whether the STOP-Bang score predicts hypoxia as measured by pulse oximetry. The results are summarized in Figure 2. The left panel presents the expected and observed numbers of desaturation events for each possible level of the STOP-Bang measure. As shown in Figure 2, higher levels of the STOP-Bang measure were associated with more SpO_2 desaturation events both below 90% and 88%. Even those with a STOP-Bang of 0 are still expected to have 30 SpO_2 desaturation events below 90% and approximately 5 to 10 SpO_2 events below 88% across the 2-day postoperative period. As STOP-Bang score increases, the expected number of desaturation events increase precipitously, almost by an order of magnitude, making an event that was uncommon very likely. The right panel of Figure 2 presents the $\log_{10}$ of the total duration spent with a SpO_2 level less than 90% and 88%. Again, higher levels of the STOP-Bang predict longer time spent with SpO_2 levels below the milder and more severe SpO_2 levels.

TABLE 2. Patient Demographic Information

Variable	Category	n
Sex	Male	20
	Female	30
ASA Class	1: Healthy	9
	2: Mild disease	29
	3: Significant disease	11
	4: Incapacitating disease	1
Anesthesia	General	21
	General and regional	25
	Regional and MAC	4
Nerve block	Yes	29
	No	21
Extremity	Left lower extremity	10
	Left upper extremity	16
	Right lower extremity	10
	Right upper extremity	14
Home CPAP	Yes	2
	No	48

MAC indicates monitored anesthesia care (sedation provided); CPAP, continuous positive airway pressure device.

We tested our second hypothesis by evaluating the 4 outcomes listed above, but instead of treating the STOP-Bang as a single measure, we examined each constituent element. Results for the element-based analysis are presented in Table 3. As can be seen in the table, age and BMI consistently associate with the number of SpO_2 desaturation events at both 90% and 88%. Specifically, older and heavier patients experience more desaturation events. The other 6 STOP-Bang elements do not consistently predict increases in number of SpO_2 desaturation events, and several of the elements have negative, nonsignificant coefficients.

Age was a broadly consistent predictor of the duration of SpO_2 desaturation, although an insignificant predictor of the time spent with a SpO_2 level less than 90%. Hypertension was a significant predictor of SpO_2 desaturation time less than 90% but not less than 88%. Snoring was a significant predictor of the duration of severe SpO_2 desaturation (88%) but not mild desaturation (90%). The direction of the association between snoring and the duration of desaturation is in the reverse direction from what would have been predicted from the total STOP-Bang score. We expected snoring to increase the duration of severe hypoxemia, but the results suggest that snoring reduced the duration of severe hypoxemia. These results suggest that the individual elements of the STOP-Bang that predict the number of SpO_2 desaturation events are not necessarily the same as those that predict SpO_2 desaturation duration.

We examined our third hypothesis by analyzing the quality-of-life metrics reported in the patient journals to determine their ability to predict hypoxemic events. The results of this analysis are presented in Table 4. Consistent with the previous analyses, the STOP-Bang score predicted all of the outcomes. Additionally,

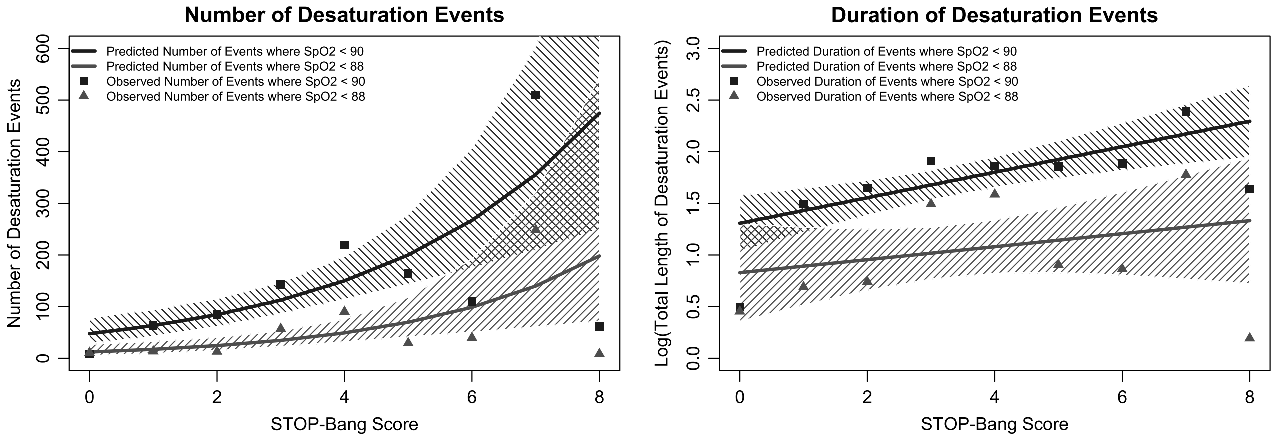

FIGURE 2. Number and duration of desaturation events increases as STOP-Bang score increases. Negative binomial regression was used to generate the predicted number of SpO_2 desaturation events and linear regression was used to generate the predicted log_{10} of the total duration of the desaturation across the 2-day postoperative period. The predicted values are indicated by the solid lines (grey for SpO_2 <90%; black for SpO_2 <88%). The hatched areas around the solid lines indicate the 95% confidence intervals for the predicted values. The observed values are plotted with grey squares for SpO_2 desaturation events less than 90% and black triangles for SpO_2 desaturation events less than 88%.

and somewhat predictably using home CPAP reduced the number of desaturation events. Of interest was taking opiate analgesics also decreased the number of desaturation events.

DISCUSSION

As the population ages, outpatient surgeries are expected to become more commonplace, being performed on patients with increasing numbers of comorbid afflictions and risk factors that may complicate surgery recovery at home. Our study revealed several interesting associations meriting patient safety considerations. This is especially important, given the absence of data about early ambulatory anesthesia/surgery recovery at home and concerns of postoperative respiratory events.[1–5]

In this light, there are several notable results from the present study. First, the frequency and duration of hypoxemia in our patient sample increased as STOP-Bang scores increased. For individuals with STOP-Bang scores in the range of 0 to 1, we would expect a few desaturation events and a very brief time spent with SpO_2 < 88%. By contrast, individuals with high STOP-Bang scores greater than 4 would be expected to have a very large number of SpO_2 and spend a relatively longer time with SpO_2 less than 88%. Given that low SpO_2 levels may indicate greater risk for negative patient outcomes,[2,4–6] knowledge of a patient's STOP-Bang score may be a useful metric for risk management strategies relevant to ambulatory surgery patients.

Second, individual elements of the STOP-Bang varied in their relationship to both the number and duration of SpO_2 desaturation events. Although the STOP-Bang tool is well appreciated for its noninvasive, time-sensitive predictive value,[7–9] we were interested in determining what, if any, specific elements of the tool were more predictive of postoperative desaturation events. Our analysis suggests that both BMI and age were the strongest predictors, with BMI having the largest effect size. In our study, participants with a BMI greater than 35 experienced a 466% increase in the risk of mild hypoxemic events (SpO_2 < 90%) and a 1473% increase in the risk of severe events (SpO_2 < 88%). Similarly for each additional year in age, we found a 3% increase in the risk of desaturation mild hypoxemic events (SpO_2 < 90%) and an 8% increase in the risk of severe hypoxemic events (SpO_2 < 88%). Unexpectedly, individuals who snore spend less time below a SpO_2 threshold of 88%. Based on these results, it is clear that future

TABLE 3. Contribution of Individual STOP-Bang Elements to the Prediction of the Number and Duration of Events SpO_2 less than 90% and less than 88%

	No. Desaturation Events		Total Duration of Desaturation	
	SpO_2 < 90%	SpO_2 < 88%	SpO_2 < 90%	SpO_2 < 88%
Snore	0.12 (0.32)	−0.06 (0.46)	−0.07 (0.17)	−0.62* (0.26)
Tired	0.18 (0.32)	−0.24 (0.42)	0.15 (0.16)	0.17 (0.23)
Apnea	−0.41 (0.50)	0.18 (0.72)	−0.18 (0.28)	−0.25 (0.42)
Hypertension	0.43 (0.30)	0.31 (0.44)	0.36* (0.17)	−0.04 (0.25)
BMI	1.54* (0.61)	2.69** (0.88)	0.64 (0.33)	0.84 (0.50)
Age	0.03* (0.01)	0.08*** (0.02)	0.02 (0.02)	0.03** (0.01)
Neck	−0.82 (0.62)	−0.90 (0.89)	−0.40 (0.34)	−0.13 (0.51)
Male	0.64 (0.34)	0.56 (0.49)	0.20 (0.19)	0.04 (0.27)
Intercept	2.31** (0.78)	-2.02^{+} (1.16)	0.54 (0.43)	−0.89 (0.64)

Standard errors in parentheses. Negative binomial regression was used to analyze the number of SpO_2 desaturation events, and linear regression was used to analyze the log_{10} of the total duration of the desaturation across the 2-day postoperative period.

Statistical significance is noted by the following symbols: *P < .05, **P < .01, ***P < .001.

TABLE 4. Quality of Life Predictors of the Number and Duration of SpO_2 Desaturation Events Below 90% and 88%

	No. Desaturation Events		Total Duration of Desaturation of Events	
	SpO_2 < 90%	SpO_2 < 88%	SpO_2 < 90%	SpO_2 < 88%
STOP-Bang	0.32*** (0.07)	0.37*** (0.11)	0.14*** (0.04)	0.15* (0.07)
Anesthetic	−0.33 (0.24)	−0.03 (0.41)	−0.20 (0.14)	0.27 (0.27)
Prescription pain medication	−1.00** (0.37)	−1.91** (0.63)	−0.31 (0.22)	−0.35 (0.42)
Total sleep	0.03 (0.02)	0.03 (0.03)	0.01 (0.01)	−0.003 (0.02)
Happy mood	−0.44 (0.31)	−0.87 (0.53)	−0.26 (0.18)	0.06 (0.35)
Home CPAP	−1.93** (0.66)	−2.99** (1.13)	−0.78* (0.38)	−1.70* (0.73)
Intercept	4.08*** (0.52)	3.22*** (0.88)	1.56*** (0.30)	0.69 (0.58)

Standard errors in parentheses. Negative binomial regression was used to analyze the number of SpO_2 desaturation events, and linear regression was used to analyze the $\log_{10}$ of the total duration of the desaturation across the 2-day postoperative period. STOP-Bang score was the number of symptoms. Anesthetic was 0 for general and 1 for regional or monitored care. Prescription pain medication was the average number of times that the patient reported taking an opiate. Total amount of sleep was measured in hours. Happy mood was the average number of times that a person said they were happy. Home CPAP was whether the patient had a home CPAP machine. Statistical significance is noted by the following symbols: *P < .05, **P < .01, ***P < .001.

study should examine how the individual elements of the STOP-Bang and its cumulative score relate to a variety of patient outcomes and not just risk for OSA.

Third, several of the quality-of-life metrics were associated with SpO_2 desaturation. Surprisingly, opioid use seemed to have a protective effect, diminishing the total number of desaturation events in the first 48 hours after surgery. Because 46 of the 50 patients used opioid at least once during the postoperative phase, this result is not due to low levels of use. Furthermore, only 9 of the 50 patients reported opioid use at every diary entry, which is consistent with prescribed dosages and indicates minimal levels of risky opioid use. Importantly, patients are educated on analgesic use at both sites. The efficacy and merit of this may be evident in patients who were compliant, comfortable, and not oversedated. Opiates exert a positive effect when used properly, but their misuse is problematic. These results suggest that further investigations into opioid used in the postoperative period deserve attention in future studies.

Finally, home CPAP use had a protective association as both number and duration of desaturation events with SpO_2 less than 88% were significantly less frequent and shorter. To put this in perspective, both of the patients who used the CPAP device at home had the maximum STOP-Bang scores. Accordingly, we would predict they would have 198 desaturation events where SpO_2 is less than 88%, when one of the patients had 16 events and the other had only 1 (the other outcomes had similarly stark differences for these 2 patients). Although 2 patients are not enough to make definitive conclusions, we feel that this dramatic decrease warrants attention in future studies. The current study design cannot address causality of any observation.

In his recent editorial critiquing the risks of mismanaging patients with OSA, Benumof opined, "the first step in fixing a problem is identifying the problem."[6] His concerns are validated by the considerable morbidity and mortality that may be associated with the in-patient surgical and anesthetic care of those with OSA and the inconsistent use of STOP-Bang as a screening tool.[16] We extended on his concerns in our work with the growing population of ambulatory surgical patients.

We have entered the era of enhanced recovery after surgery (ERAS), a paradigm shift in the way that perioperative care is delivered to patients.[17–19] Hallmarks of ERAS are the critical reexamination of traditional practices, substituting evidence-based interventions where appropriate, and comprehensively detailing all aspects of a patient's journey through their course of care. Although ERAS has primarily focused on patients undergoing in-patient colorectal cancer surgery, we believe that significant benefits can be reaped if similar approaches were to be applied to ambulatory surgical patients, as research illuminates issues in the postoperative (at home) phase of care.

Limitations

The current results should be interpreted in the light of their limitations. Although patient compliance with both the journal entries and oximeter were excellent, compliance with the protocol cannot be assured. The reliability and validity of our sleep, pain, and mood tools were based on the literature[12,20–25] yet have not previously been used in the setting of a patient's home during surgical recovery. We only included patients having peripheral orthopedic surgery. Finally, it was not possible to have home oximetry before surgery because of the logistics of the ambulatory patient process (surgical and anesthetic).

CONCLUSIONS

The STOP-Bang score was directly predictive of desaturation events during their first 48 hours after discharge from ambulatory surgery. Patient BMI and age were the most powerful predictors of the number of SpO_2 desaturation events, and age was the strongest predictor of the duration of those events. Information gleaned from the journal entries revealed qualitative elements that should be given consideration in future care decisions, such as encouraging the use of home CPAP in patients with high STOP-Bang scores and aggressive education regarding use of opiates.

REFERENCES

1. Society of Anesthesia and Sleep Medicine. Closed claims project and its registries. Available at: http://depts.washington.edu/asaccp/projects/obstructive-sleep-apnea-osa-death-near-miss-registry. Accessed June 30, 2016.
2. Lee LA, Caplan RA, Stephens LS, et al. Postoperative opioid-induced respiratory depression: a closed claims analysis. *Anesthesiology.* 2015;122:659–665.
3. Coté CJ, Posner KL, Domino KB. Death or neurologic injury after tonsillectomy in children with a focus on obstructive sleep apnea: Houston, we have a problem! *Anesth Analg.* 2014;118:1276–1283.
4. Sessler DI. Preventing respiratory depression. *Anesthesiology.* 2015;122:484–485.

5. Brown KA, Brouillette RT. The elephant in the room: lethal apnea at home after adenotonsillectomy. *Anesth Analg*. 2014;118: 1157–1159.
6. Benumof JL. Mismanagement of obstructive sleep apnea may result in finding these patients dead in bed. *Can J Anaesth*. 2016;63:3–7.
7. Chung F, Subramanyam R, Liao P, et al. High STOP-Bang score indicates a probability of obstructive sleep apnoea. *Brit J Anaesth*. 2012;108:768–775.
8. Ramachandran SK, Kheterpal S, Consens F, et al. Derivation and validation of a simple perioperative sleep apnea prediction score. *Anesth Analg*. 2010;110:1007–1015.
9. Silva GE, Vana KD, Goodwin JL, et al. Identification of patients with sleep disordered breathing: comparing the four-variable screening tool, STOP, STOP-Bang, and Epworth Sleepiness Scales. *J Clin Sleep Med*. 2011;7: 467–472.
10. Koenig L, Gu Q. Growth of ambulatory surgical centers, surgery volume, and savings to Medicare. *Am J Gastroenterol*. 2013;108:10–15.
11. Webster LR, Cochella S, Dasgupta N, et al. An analysis of the root causes for opioid-related overdose deaths in the United States. *Pain Med*. 2011;12:S26–S35.
12. Zisapel N, Tarrasch R, Laudon M. A comparison of visual analog scale and categorical ratings in assessing the patient's estimate of sleep quality. In Lader M, Cardinali D, Pandi-Perumal S (Eds.), Sleep and Sleep Disorders: A Neuropsychopharmacological Approach. 2006;220–222. New York: Springer US.
13. NONIN(R) Wrist Ox(R) 3100 Operator's Manual. Plymouth: NONIN Medical, Inc. 2005.
14. *Pulse Oximetry: Wearable Digital Pulse Oximeter for the Ambulatory Patient*. Plymouth: NONIN Medical, Inc.; 2006.
15. Nigro CA, Aimaretti S, Gonzalez S, et al. Validation of the WristOx 3100 oximeter for the diagnosis of sleep apnea/hypopnea syndrome. *Sleep Breath*. 2009;13:127–136.
16. Cordovani L, Chung F, Germain G, et al. Perioperative management of patients with obstructive sleep apnea: a survey of Canadian anesthesiologists. *Can J Anaesth*. 2016;63:16–23.
17. Varadhan KK, Lobo DN, Ljungqvist O. Enhanced recovery after surgery: the future of improving surgical care. *Crit Care Clin*. 2010;26: 527–547.
18. Scott NB, McDonald D, Campbell J, et al. The use of enhanced recovery after surgery (ERAS) principles in Scottish orthopaedic units—an implementation and follow-up at 1 year, 2010–2011: a report from the Musculoskeletal Audit, Scotland. *Arch Orthop Trauma Surg.* 2013;133: 117–124.
19. Kehlet H, Dahl JB. Anaesthesia, surgery, and challenges in postoperative recovery. *Lancet*. 2003;362:1921–1928.
20. DeLoach LJ, Higgins MS, Caplan AB, et al. The visual analog scale in the immediate postoperative period: intrasubject variability and correlation with a numeric scale. *Anesth Analg*. 1998;86: 102–106.
21. Maldonado CC, Bentley AJ, Mitchell D. A pictorial sleepiness scale based on cartoon faces. *Sleep*. 2004;27:541–548.
22. Zisapel N, Nir T. Determination of the minimal clinically significant difference on a patient visual analog sleep quality scale. *J Sleep Res*. 2003; 12:291–298.
23. Engleman H, Douglas N. Sleep 4: sleepiness, cognitive function, and quality of life in obstructive sleep apnoea/hypopnoea syndrome. *Thorax*. 2004;2004:618–622.
24. Goncalves MA, Paiva T, Ramos E, et al. Obstructive sleep apnea syndrome, sleepiness, and quality of life. *Chest*. 2004;125: 2091–2096.
25. Yadeau JT, Liu SS, Rade MC, et al. Performance characteristics and validation of the Opioid-Related Symptom Distress Scale for evaluation of analgesic side effects after orthopedic surgery. *Anesth Analg*. 2011;113: 369–377.