Using the STOP-BANG questionnaire to predict hypoxaemia in patients recovering from noncardiac surgery: a prospective cohort analysis

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Abstract

Background: The STOP-BANG questionnaire is a validated, eight-point dichotomized scale used to screen preoperative patients for obstructive sleep apnoea. Sleep apnoea causes hypoxaemia, and nocturnal oxygen desaturation is diagnostic in these patients. We tested the hypothesis that STOP-BANG score is associated with hypoxaemia after noncardiac surgery.

Methods: This analysis was a sub-study of VISION, a prospective cohort study of perioperative cardiovascular events. With institutional review board approval, we included 630 patients in the final analysis. We assessed the association between the STOP-BANG score and postoperative hypoxaemia, defined as integrated area under the curve of Sp_{O_2} saturation of 90% per h using median quantile regression. Secondarily, we selected a subset of STOP-BANG questions that best predicts postoperative hypoxaemia using 'Least Absolute Shrinkage and Selection Operator' method, and then assessed the association between the new score based on the selected questions and the primary outcome using quantile regression.

Results: The median [q1, q3] area under Sp_{O_2} of 90% per h was 0.09 [0.02, 0.39] %-h. The STOP-BANG score was not associated with hypoxaemia, with a multivariable slope coefficient of 0.002 (95% CI: −0.01, 0.01) %-h for a unit increase in the score (P=0.76). Secondarily, no association was found between the new score based on the two retained STOP-BANG questions, treatment for hypertension and neck circumference >40 cm, and the primary outcome with a multivariable slope coefficient of 0.03 (98.3% CI: −0.01, 0.06) %-h/score (P=0.07).

Conclusions: The STOP-BANG score does not predict hypoxaemia in adults recovering from noncardiac surgery.

Clinical trial registration: NCT00512109.

Key words: anaesthesia; apnoea; obstructive sleep; care; postoperative; hypoxaemia; oximetry; pulse

Editor's key points

- Obstructive sleep apnoea is a risk factor for postoperative hypoxaemia
- The STOP BANG questionnaire can identify obstructive sleep apnoea
- The STOP BANG questionnaire doesn't seem to predict postoperative hypoxaemia

Postoperative hypoxaemia was recognized as a significant problem almost five decades ago.[1] Prospective cohort studies suggest that oxygen desaturation is common, and often severe and prolonged.[2] Many factors are associated with postoperative desaturation including type of surgery,[3] duration and type of anaesthesia,[4] obesity,[5] and pre-existing pulmonary compromise.[6] An additional factor, one thought to be especially important, is obstructive sleep apnoea (OSA).[7][8]

OSA is a disorder characterized by recurrent periods of complete airflow cessation (apnoea) or partial airflow cessation (hypopnea) associated with oxygen desaturations (hypoxemia) or arousals from sleep.[9] Recent literature concludes that OSA is associated with postoperative cardiac events, respiratory failure, and critical care admission.[10–13] This association is especially concerning because up to 20% of elective surgical patients have OSA, most of whom lack a formal diagnosis.[8][14] General anaesthesia, especially in combination with opioids,[15] may contribute to a decreased response to hypopnoea or apnoea after surgery, leading to higher rates of hypoxaemia in OSA patients. Although various pre-surgical screening surveys for OSA are available,[16] the best-known, most sensitive, specific,[17] and consistently validated approach is the STOP-BANG questionnaire.[16][18–20]

We thus tested the primary hypothesis that there is an association between OSA severity (as assessed by an increasing STOP-BANG score)[17] and hypoxaemia (defined as integrated oxygen saturation <90%) within 48 h after a noncardiac surgery. Secondarily, we evaluated whether a subset of questions from the STOP-BANG questionnaire was sufficient to predict postoperative hypoxaemia. Both questions were defined *a priori*.

Methods

Our analysis was a sub-study of the **V**ascular events **I**n **S**urgery pat**I**ents c**O**hort evaluatio**N** (VISION), a 40 000-patient prospective cohort study, focused on perioperative cardiovascular events (NCT00512109).[21][22] We have previously reported the incidence, severity, and duration of postoperative hypoxaemia in the same subset of the VISION patients.[2] With Cleveland Clinic Institutional Review Board (IRB) and the VISION steering committee approval, we consented and enrolled 1250 patients who were at least 45 yr of age and were undergoing noncardiac inpatient surgery with general and/or regional anaesthesia, at the Cleveland Clinic Main Campus. A deliberate cross-section of surgical patients was selected to reflect the noncardiac surgical population at our institution. We excluded patients who were not expected to stay at least one night in the hospital, who received only local or topical anaesthesia, who received monitored anaesthesia care, or had previously participated in the VISION study. As most institutions regard oxygen saturations <90% in a patient on the surgical ward as cause for concern and respiratory intervention, we chose this as our primary threshold value. However, we also performed sensitivity analyses on oxyhaemoglobin saturation (Sp_{O_2}) <85%, <95% and a time-weighted average (TWA) of Sp_{O_2}. A formal statistical analysis plan was formulated before this

sub-study, and the project was approved by the Cleveland Clinic Institutional Review Board.

Patient characteristics and morphometric characteristics were recorded in our pre-anaesthetic clinical evaluation. We recorded all eight components of the STOP-BANG score (Supplementary Appendix 3) preoperatively. The questionnaire consists of eight yes/no questions scored as zero or one for a maximum score of eight and a minimum score of 0. STOP-BANG scores greater than three have a 93% sensitivity for moderate OSA, but a specificity <50%.[17] OSA screening thus tends to over-diagnose a fraction of normal patients.

Intraoperatively, our Perioperative Health Documentation System electronically recorded surgical and anaesthetic details. We attempted to record postoperative Sp_{O_2} continuously for up to 48 h, or until hospital discharge (whichever occurred earlier). Saturation monitoring started upon discharge from the post-anaesthesia care unit, step-down unit, or critical care unit. The pulse oximeter (Model Nellcor OxiMax N-600x, Covidien, Dublin, Ireland) was mounted on a wheeled i.v. pole, along with an uninterruptible power supply and computer; the entire unit weighed about 32 kg. Importantly, all caregivers involved with these patients were completely blinded to pulse oximeter readings and all alarms were disabled. These data were recorded internally, and subsequently transferred to a secure database. Pulse oximeter waveforms were recorded, but data were averaged to one-min values for this analysis.

Patients were encouraged to remain connected continuously, but were allowed to disconnect the system when mobilized or attending to personal hygiene. Study personnel visited each patient at least four times daily, including nights and weekends, to promote compliance, but of course it was always a patient's prerogative to discontinue study participation.

Data analysis

Among 1250 patients who met the inclusion criteria, we excluded patients who had fewer than 12 h of continuous monitoring, gaps in the saturation monitor records exceeding 4 h, or overall unrecorded time exceeding 30% of total monitoring time.

The primary outcome was defined as the integrated area under the curve of Sp_{O_2} saturation of 90% per h. This outcome characterizes both the duration and severity of hypoxemia because both longer duration and lower Sp_{O_2} would result in a larger area under the threshold of 90%, while adjusting for the duration of Sp_{O_2} monitoring. Linear interpolation was used when measurements were missing.

We used multivariable median quantile regression with bootstrapped standard errors to assess the association between the primary outcome and the STOP-BANG score which ranged from zero to eight.[23] We expected the primary outcome to be highly skewed and thus selected quantile regression instead of ordinary least squares linear regression, because the technique is robust.

Ten pre-specified confounders were controlled for in the analysis including: type of surgery, duration of surgery, ASA score, Mallampati score, Sp_{O_2} at incision, preoperative diagnosis of congestive heart failure, intraoperative opioid dose (in i.v. morphine equivalents, the conversions are provided in Supplementary Appendix 1), use of intraoperative neuromuscular blocking agents, use of nitrous oxide, and postoperative epidural analgesia (Supplementary Appendix 4). Additionally, we conducted three sensitivity analyses, in which the outcomes were area under an Sp_{O_2} saturation of (i) 95% and (ii) 85% per h, and (iii) time-weighted average (TWA) of Sp_{O_2}. The significance criterion was 0.017 for each sensitivity analysis (i.e. 0.05/3, Bonferroni correction).

Secondary analyses

We selected a subset of the STOP-BANG questions that best predicts postoperative hypoxaemia, using 'Least Absolute Shrinkage and Selection Operator' method.[24] The penalty parameter was chosen to minimize the 10-fold cross-validation error (optimize prediction). Then, we evaluated the association between the new score (summing up the selected STOP-BANG questions) and the area under Sp_{O_2} of 90% per h, using the median quantile regression. In addition, we assessed the associations between the STOP-BANG score and (i) use of continuous positive airway pressure (CPAP) therapy and (ii) use of oxygen administration by mask from postoperative day (POD) one to POD three, each using a multivariable logistic regression. In each secondary analysis, we adjusted for the same set of pre-specified confounders as in the primary analysis. In the CPAP and oxygen use analyses, we also adjusted for preoperative use of CPAP or use of home oxygen by mask. The Bonferroni correction was used to adjust for the multiple analyses; thus the significance criterion was 0.017 for each secondary analysis.

This study was a sub-study of the VISION trial; we included all patients meeting the inclusion/exclusion criteria. With 630 available patients, we had more than 90% power to detect a Pearson's correlation of 0.13 or greater, between the primary outcome and the STOP-BANG score assuming a null correlation of zero, at a 0.05 significance level. SAS software version 9.4 (SAS Institute, Cary, NC, USA) and R software version 3.1.2 (The R Foundation for Statistical Computing, Vienna, Austria) were used for statistical analyses and graphics.

Results

Among patients who met inclusion criteria, 1250 consented to participate. However, only 630 patients were included in the final analyses (Fig. 1); by far the most common reason for exclusion was that patients chose to discontinue monitoring. Qualitatively, patients were most likely to discontinue monitoring when they had recovered from the acute effects of surgery and began to mobilize. Patient characteristics and perioperative characteristics of the analysis cohort (N=630) are provided in Table 1. Patient characteristics and perioperative characteristics of the consented cohort (N=1250), compared with the analysed cohort (N=630) and the excluded cohort (N=620) are provided in Supplementary
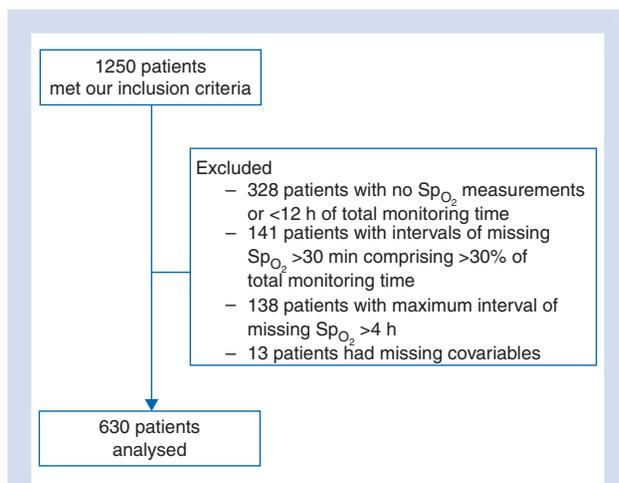

1250 patients met our inclusion criteria

Excluded
– 328 patients with no Sp_{O_2} measurements or <12 h of total monitoring time
– 141 patients with intervals of missing Sp_{O_2} >30 min comprising >30% of total monitoring time
– 138 patients with maximum interval of missing Sp_{O_2} >4 h
– 13 patients had missing covariables

630 patients analysed

Fig 1 Study Flow Chart.

Appendix 2. The excluded patients were comparable with the analysed patients as is evident from the absolute standardized differences (ASD) in Supplementary Appendix 2.

Approximately 10% of patients with STOP-BANG score of zero or one averaged at least 10 min per h with raw Sp_{O_2} values below 90%, and approximately 5% of them averaged at least 20 min per h with raw Sp_{O_2} values below 90%. Likewise, approximately 18% of patients with STOP-BANG score of two or three, 20% of patients with score of four or five, and 22% of patients with score of six to eight averaged at least 10 min per h with raw Sp_{O_2} <90% (Fig. 2A). Consistent results were seen with duration of hypoxaemia with cut-offs of Sp_{O_2} of <95% (Fig. 2B) and Sp_{O_2} of <85% (Fig. 2C). The distribution of Sp_{O_2} as a function of postoperative time and increasing STOP-BANG scores is displayed in Fig. 3. Generally, measured Sp_{O_2} values decreased as postoperative time increased, irrespective of STOP-BANG scores.

The median STOP-BANG score was three [q1, q3: 2, 5], and the median area under the curve of an Sp_{O_2} saturation of 90% per h was 0.09 [0.02, 0.39] %-h. The unadjusted association between STOP-BANG score and area under the curve of an Sp_{O_2} saturation of 90% per h is displayed in Fig. 4. No significant association was detected between the STOP-BANG score and the median area under the curve of an Sp_{O_2} saturation of 90% per h (P=0.76). The estimated multivariable slope coefficient was 0.002 (95% CI: −0.01, 0.01) %-h/score, which was the estimated change in the median area under Sp_{O_2} of 90% per h for a unit increase in the STOP-BANG score. Consistent results were found in all three sensitivity analyses: no significant association was found between the STOP-BANG score and area under an Sp_{O_2} saturation of 95% per h (0.03 (98.3% CI: −0.08, 0.13); P=0.56), under 85% per h (0 (−0.001, 0.002); P=0.79), or time-weighted average of Sp_{O_2} (−0.07 (−0.20, 0.07); P=0.32) (Table 2).

After variable selection by minimizing prediction error using the 'Least Absolute Shrinkage and Selection Operator' method, only two of the eight STOP-BANG questions remained, which were 'Are you or have you been treated for high blood pressure' and 'Neck circumference >40 cm'. Again, no significant association was found between the new score based on these two selected questions and the median of area under Sp_{O_2} of 90% per h, with a multivariable slope coefficient of 0.03 (98.3% CI: −0.01, 0.06) %-h/score (P=0.07, Supplementary Appendix 5).

Forty-seven (7.5%) patients used CPAP therapy and 15 (2.4%) patients received oxygen administration by mask from POD one to POD three. Higher (worse) STOP-BANG scores were associated with increased odds of using CPAP postoperatively: 1.54 (98.3% CI: 1.06, 2.24), P=0.006, but not using oxygen mask: 1.18 (0.79, 1.77), P=0.03 (>significance criterion of 0.017). A total of 426 (68%) patients received oxygen by nasal cannula, but usually just for a few postoperative h.

Discussion

Overnight polysomnography is the 'gold standard' for detection of OSA.[25] However, its use in our prospective cohort study was precluded by its cost and complexity. Instead, we used the STOP-BANG score. In the earliest version of the score (2008), a score of greater than or equal to three was considered a positive screen for OSA.[17] More recently, the same investigators concluded that the risk of moderate/severe OSA increased from 36% at a STOP-BANG score of three to 60% at a STOP-BANG score of seven.[19] Increasing STOP-BANG scores thus correlate with higher probability of moderate-to-severe OSA.

Cyclical oxygen desaturation occurs in all patients with OSA and is a part of the standard diagnostic definition of this

Table 1 Patient characteristics and perioperative characteristics of the analysis cohort (*N*=630). Summary statistics were presented as mean (SD), median [q1, q3], median [q1, q3] (min, max) and No. (%), as appropriate. Superscripts represent number of patients with missing value.

Variable No. (%)	Summary statistics
Age, yr mean (range)	63 (54, 91)
Gender, male	355 (56)
ASA physical status	
I	4 (1)
II	170 (27)
III	387 (61)
IV	69 (11)
Mallampati score	
I	197 (31)
II	337 (54)
III	87 (14)
IV	5 (1)
Preoperative comorbidities	
Deep vein thrombosis	53 (8)
Atrial fibrillation	53 (8)
Stroke	24 (4)
Coronary artery disease	112 (18)
Congestive heart failure	37 (6)
Recent catheterization (<12 months)	25 (4)
Aortic stenosis	9 (1)
Peripheral vascular disease	49 (8)
Diabetes	118 (19)[1]
Peptic ulcer	26 (4)[3]
Tobacco use	345 (55)[1]
Sleep apnoea	116 (18)
Hypertension	393 (62)
Chronic obstructive pulmonary disease	56 (9)
Dialysis	3 (1)
Asthma	67 (11)
Interstitial lung disease	8 (1)
Lobectomy	5 (1)
Pneumonectomy	5 (1)
Tuberculosis	9 (1)
Cystic fibrosis	4 (1)
Pulmonary sarcoidosis	4 (1)
Lung cancer	11 (2)
Surgical Characteristics	
Most frequent types of surgery	
Major spine surgery	112 (18)
Intra-abdominal surgery	102 (16)
Stomach surgery	67 (11)
Major hip-pelvic surgery	61 (10)
Knee arthroplasty	58 (9)
Duration of surgery, h	4.0 [3.1, 5.2]
Endoscopic surgery	174 (28)
Open surgery	478 (76)
Minimum invasive surgery	27 (4)
General anaesthesia	561 (89)
Spinal anaesthesia	64 (10)
Nerve block anaesthesia	42 (7)
Epidural anaesthesia	65 (10)
Baseline systolic blood pressure, mm Hg	139.5 (23.4)
Baseline heart rate, bpm	74.5 (12.8)
Baseline Sp_{O_2}	98.6 (1.7)
Use of nitrous oxide	60 (10)

Continued

Table 1 *Continued*

Variable No. (%)	Summary statistics
Average PEEP, mm Hg	3.9 (1.7)[65]
Total dose of opioid (IV morphine equivalent), mg	25 [18, 34]
Total dose of neuromuscular blocking agent(rocuron), mg	82.5 [55, 110]
Postoperative analgesia	
Use of epidural analgesia	97 (15)
Use of patient-control analgesia	253 (40)
Use of opioid	
Fentanyl	249 (40)
Morphine/Hydromorphone	215 (34)
Meperidine	8 (1)
None	158 (26)
Postoperative events	
Adult respiratory distress syndrome	1 (<1)
Pneumothorax	0 (0)
Respiratory failure	11 (2)
Re-intubation	9 (1)

pathology.[9 25] Based on this premise we proposed our hypothesis that higher STOP-BANG scores (more predictive of OSA), would also predict worse desaturation in OSA patients postoperatively. Nonetheless, our results did not support increasing STOP-BANG scores in predicting hypoxaemia defined as an area under Sp_{O_2} of <90% in adults recovering from noncardiac surgery. These results were similar when the analysis was conducted on the basis of area under an Sp_{O_2} of 95% or 85%, or a time-weighted average of Sp_{O_2} over the entire postoperative monitoring period (Table 2).

OSA patients have a breathing pattern characterized by either a near-complete cessation (>90% reduction) of airflow and/or a partial cessation of airflow (>30% reduction) for a duration of at least 10 s and associated with a desaturation of at least 3% or an arousal from sleep.[25] However, nadir oxygen desaturation in OSA patients may not descend below 90%. For example, an OSA patient who normally has an oxygen saturation of 98% while awake and cycles down to 94% during flow reduction periods, meets the criteria for a polysomnography diagnosis of OSA — without ever having an Sp_{O_2} of <90% and thus reaching our desaturation threshold. The choice of threshold, though, does not seem to be critical as results were consistent when analyses were conducted based on area under <95% and <85%. Furthermore, time-weighted average Sp_{O_2} was 94.6% with no significant correlation to STOP-BANG score.

We chose an area under Sp_{O_2} <90% per h as our primary outcome, as this defines the outcome both in terms of severity and duration of hypoxaemia. For example, an oxygen saturation of 80% for 10 min (1.7%-h) is presumably worse than an oxygen saturation of 88% for 15 min (0.5%-h), and the difference is well reflected in area-under-the-curve analyses. Median area under the 90% saturation curve was 0.09%-h which corresponds to, for example, five min per h with a saturation of 89% or one min per h with a saturation of 85%. The multivariable slope coefficient for area under 90% saturation was 0.002%-h/score which means that for every unit increase in STOP-BANG score, the Sp_{O_2} decreases by <0.1% for one min per h, an amount that was both non-significant and obviously clinically meaningless. The clinical correlate of the trivial reduction in saturation with increasing STOP-BANG scores is that higher scores do not predict more hypoxaemia. High STOP-BANG scores *per se* thus do not appear to be a sound basis for special postoperative monitoring or treatment.
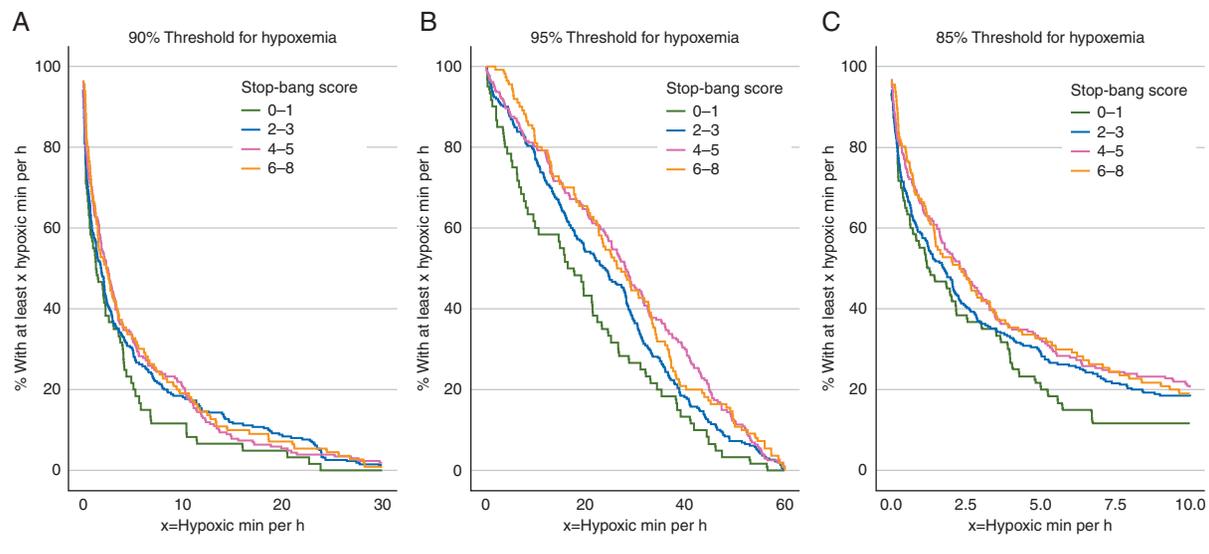
Fig 2 Incidence of patients with an average number of min per h in hypoxaemia >X during monitoring. The threshold for hypoxaemia is (A) 90%, (B) 95%, and (C) 85%. The green line represents patients with STOP-BANG score of zero or one; the blue line represents patients with STOP-BANG score of two or three; the pink line represents patients with STOP-BANG score of four or five; and the orange line represents patients with STOP-BANG score of six to eight.

Our results are somewhat surprising in that previous studies have linked OSA with both postoperative desaturation and complications. Liao and colleagues[7] concluded in a retrospective matched cohort study that patients with diagnosed OSA have an increased incidence of postoperative complications, the most common of which was oxygen desaturation. Kaw and colleagues[10], in a meta-analysis of 3942 patients saw that postoperative desaturation; respiratory failure, postoperative cardiac events and ICU transfers were higher in patients with OSA. Mutter and colleagues[13], in a recent matched cohort analysis found increased risk of postoperative respiratory complications, in patients with both diagnosed and undiagnosed OSA. All of these relationships are complicated by slight increases in pain sensitivity in OSA patients which, in turn, might promote opioid administration.[26] Chia and colleagues[11] confirmed the direct association of preoperative STOP-BANG scores with postoperative ICU admission, however, the STOP-BANG scores likely influenced physician behaviour, so a causal relationship should not be assumed.

A further consideration is that patients with higher STOP-BANG scores are generally sicker than those with lower scores[27] and that may explain their propensity for ICU admission.[11] We included a cross – section of surgical patients in our analysis to avoid a bias towards a healthier patient population. Indeed, almost three quarters of our patient population was ASA III & IV (Table 1). In addition, OSA patients have a myriad of cardiovascular perturbations and a predisposition to metabolic syndrome that may contribute to poor outcomes postoperatively.[28–34] Nonetheless, a study in which four different screening tools for OSA was used preoperatively observed no association between positive screening with any tools and 30-day or one-year mortality.[16] An important consideration here was 'self-reported' OSA diagnosis and perioperative optimization programs for patients with a higher STOP-BANG score or a diagnosis of OSA, which could have influenced outcomes. Thus while STOP-BANG is an effective screening tool for OSA and OSA itself has been linked to morbidity and mortality, our data suggest that hypoxaemia is not
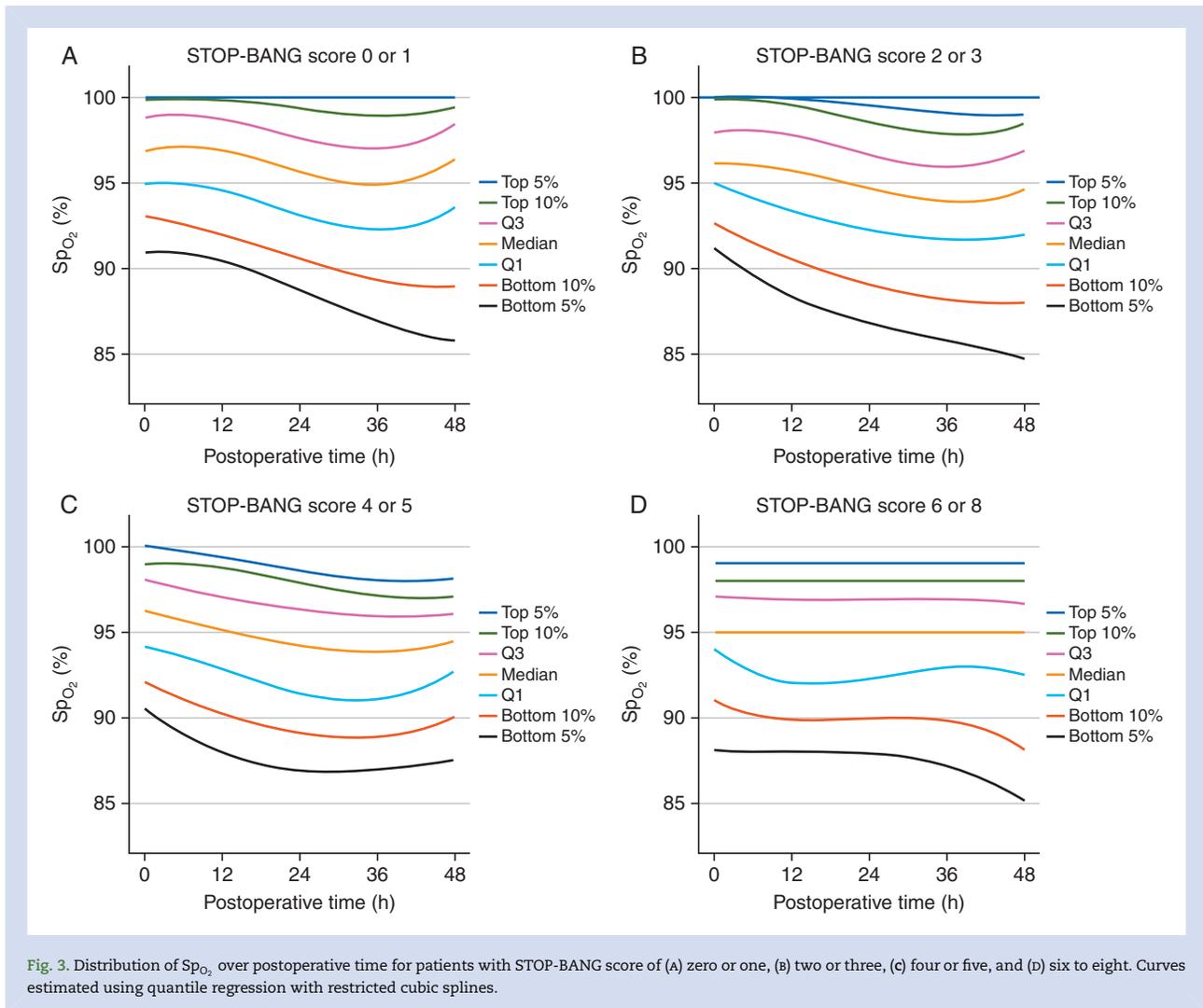
necessarily the mechanism. However, the clinical implications of this conclusion deserve cautious interpretation. Overnight polysomnography continues to be the 'gold-standard' for OSA and ventilatory patterns on such a study are clearly predictive of OSA. Indeed, we did not screen our patients with a sleep study and limited our outcomes associated with OSA and the STOP BANG score to only oxygen saturation.

As a secondary outcome we determined whether combinations of questions might adequately predict our primary outcome, area under an Sp_{O_2} of 90%. But as even the full STOP-BANG questionnaire failed to predict hypoxaemia, it is unsurprising that no subset of the components would be sufficient, and none proved statistically significant or clinically useful.

We limited the analysis to patients in whom prolonged periods of continuous Sp_{O_2} monitoring were available. A consequence is that about half the enrolled patients were excluded, mostly because patients often chose to discontinue monitoring when they became mobile. The fact that our monitoring unit was bulky and difficult to carry around during mobilization and physical therapy sessions may have also contributed to early discontinuation by some patients. Indeed, such future investigations need more portable and patient-friendly equipment, and such equipment is already being marketed.

The population included in the analysis was relatively high-risk. This is evident from the fact that median patient age was 64 yr, 72% were ASA physical status III or IV, the median duration of surgery was 4.0 h, and general anaesthetic used for 89% of the operations. Excluding patients who dropped out reduces our ability to characterize the overall incidence of postoperative hypoxaemia. But to the extent that hypoxaemia is predicted by STOP-BANG score, it should thus have been especially evident in the high-risk patients we studied. We did not observe this relationship, however, which suggests that other factors may be more importantly associated with postoperative desaturation.

We further limited analysis to patients cared for on routine surgical wards. We thus excluded the post-anaesthesia care

Fig. 3. Distribution of Sp$_{O_2}$ over postoperative time for patients with STOP-BANG score of (A) zero or one, (B) two or three, (C) four or five, and (D) six to eight. Curves estimated using quantile regression with restricted cubic splines.

unit (where OSA patients often desaturate[27]) and critical care and monitored units because patients in these situations are continuously monitored, critical oxygen desaturations are identified early, and corrective measures instituted promptly. However, saturation monitoring was initiated on these patients once they were discharged from the post-anaesthesia care unit, step-down unit, or critical care unit. We were thus most interested in what happens to these patients once they were intermittently monitored on the regular nursing floors, and where oxygen desaturation may be more common and may go unnoticed.[2]

Linear interpolation was used when Sp$_{O_2}$ measurements were missing; this is a commonly accepted way to account for consecutive missing values with non-missing value before and after within a specific level. However, it is of limited use if missing time intervals are prolonged; the median of the longest missing time interval in our study was 0.8 [Q1, Q3: 0.3, 1.9] h. Additionally, linear interpolation assumes randomly missing values and does not account for non-random missing data.

Only 7.5% of our study patients received CPAP postoperatively. However, we do not know which of these were prescribed home CPAP and, much less which actually used CPAP routinely. However, it would be unusual in our hospital to start CPAP *de novo* postoperatively; thus most of these patients likely used CPAP at home and brought their personal devices with them, though home-use may have been inconsistent. As would be expected, there was a strong relationship between higher (worse) STOP-BANG scores and postoperative CPAP use; for each unit increase in the score, the odds of CPAP use increased 1.54 (98.3% CI: 1.06, 2.24), P=0.006.

Oxygen was rarely given via face-mask in our patients (only 2.4%). This was not associated with increasing odds of a higher STOP-BANG score: 1.18 (CI: 0.79, 1.77), P=0.03 (> significance criterion of 0.017). In contrast 68% were given postoperative oxygen with a nasal cannula — although typically only for a few h. Although the delivered fraction of inspired oxygen with a nasal cannula is fairly low, any supplemental oxygen has the potential to reduce the incidence, severity, and duration of hypoxaemia. One might thus expect that oxygen administration would be highly associated with the STOP-BANG score, as supplemental oxygen would be a reasonable strategy for avoiding anticipated desaturation. Though this additional oxygen via a nasal cannula was given for only a few h postoperatively, we would not expect it to affect our final outcome where we monitored patients for 48 h or until hospital discharge, whichever came earlier. In addition, there was no association between STOP-BANG score and oxygen use via a face-mask, suggesting that other factors dominated

decisions to give supplemental oxygen, more than what could be delivered with a nasal cannula.

Chung and colleagues[35] have shown that sleep disordered breathing is worst on the third postoperative day, and that sleep disordered breathing does not return to baseline until the seventh postoperative night. Few of our patients remained hospitalized by the third postoperative day, and even fewer still tolerated monitoring. It thus remains possible that STOP-BANG scores could correlate with hypoxaemia, but only after most patients are already home. Bolden and colleagues[36], though, reported that 16% of patients desaturate to an Sp_{O_2} <90%, most often in the first 24 postoperative h. Most of their patients had only one or two episodes of desaturation to <90% which was immediately corrected by nursing intervention.[36] As continuous saturation measurements were blinded in our patients, they would not have provoked clinical intervention. Interestingly, patients in
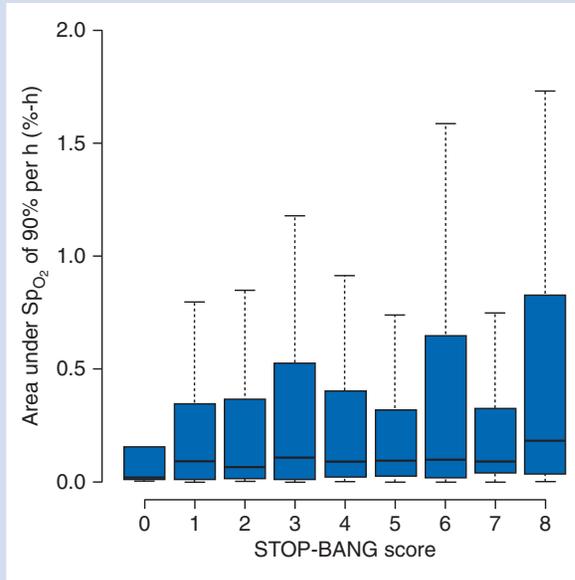

Fig. 4. Boxplot of Area under Sp_{O_2} of 90% per h for each STOP-BANG score category. No significant association was found between the STOP-BANG score and the median area under Sp_{O_2} of 90% per h, with a multivariable slope coefficient of 0.002 (95% CI: −0.01, 0.01; P=0.76) %-h for a unit increase in the score.

Bolden and colleagues[36] who were given i.v. opioids, had more than a ten-fold risk of desaturation events, which is perfectly consistent with our general conclusion that factors such as opioids may have a stronger association with postoperative desaturation than STOP-BANG scores. Further, a recent closed claims analysis by Lee and colleagues[37] showed that a majority of patients who died from respiratory events postoperatively were given opioids. However, consistent with our data, was the observation in this analysis that only a quarter of the patient population either had or was at high risk for OSA.

A limitation to our analysis is that integrated Sp_{O_2} below 90% may not be the best measure to correctly identify the episodic desaturation that best characterizes obstructive sleep apnoea. However, it is an accurate measure of the severity and duration of hypoxaemia. Shorter desaturations may indicate sleep apnoea, but *per se* are unlikely to be clinically meaningful.

A positive STOP-BANG score indicates increased risk of OSA, not that a particular patient actually has OSA. However, our primary purpose was *not* to evaluate the association between OSA and postoperative hypoxaemia; instead, it was to determine whether hypoxaemia could be predicted using information readily available to clinicians. Our results show that STOP-BANG scores do not predict hypoxaemia. A corollary is that patients with high and low STOP-BANG scores are at comparable risk. Clinicians therefore cannot easily predict which patients are most likely to desaturate postoperatively, and restrict attention and special monitoring to a single group. Instead, our results suggest that all postoperative patients are at risk and probably deserve better monitoring than they currently get in most hospitals.[38 39]

It remains possible that oxygen was more often given to patients who were thought to have high risk for OSA. However, while oxygen therapy via a face-mask was used in only 2.4% of the subjects, importantly, its use was not associated with STOP-BANG score. The STOP BANG score is a clinical risk predictor for the occurrence of OSA. And while periodic nocturnal hypoxaemia is a required feature of OSA, there are other causes in postoperative patients — most obviously opioids. Our results suggest that these other factors may be more associated with postoperative desaturation than STOP-BANG scores.

In summary, we demonstrate that progressively greater STOP-BANG scores — increasing the likelihood of clinically important OSA — did not predict the amount of postoperative hypoxaemia in a cross section of surgical inpatients. Results were similar whether hypoxemia was defined at a desaturation threshold of 95, 90, or 85%. Our surprising conclusion is thus that increasing

Table 2 Primary Analysis- Association between STOP-BANG score and area under Sp_{O_2} of 90%. Sensitivity analysis - Association between STOP-BANG score and area under an Sp_{O_2} saturation of 95% and 85% per h, and time-weighted average of Sp_{O_2} using median quantile regression with boot-strapped standard errors (N=630). *Summary statistics are presented as median [q1, q3]. †For a unit increase in the STOP-BANG score. ‡We used the Bonferroni correction adjusting for multiple analyses; the significance criterion was 0.017 for each sensitivity analysis (i.e. 0.05/3)

Outcome	Summary statistics*	Univariable analysis		Multivariable analysis	
		Slope coefficient† (95% CI)‡	P-value‡	Slope coefficient† (95% CI)‡	P-value‡
Primary analysis					
Area under an Sp_{O_2} of 90% per h, %-h	0.09 [0.02, 0.39]	0.005 (−0.01, 0.02)	0.55	0.002 (−0.01, 0.01)	0.76
Sensitivity analysis					
Area under an Sp_{O_2} of 95% per h, %-h	1.19 [0.49, 2.31]	0.06 (−0.03, 0.15)	0.10	0.03 (−0.08, 0.13)	0.56
Area under an Sp_{O_2} of 85% per h, %-h	0.01 [0.00, 0.06]	0.00 (−0.002, 0.002)	0.72	0.00 (−0.001, 0.002)	0.79
Time-weighted average of Sp_{O_2}, %	94.6 [93.1, 96.0]	−0.14 (−0.28, 0.01)	0.06	−0.07 (−0.20, 0.07)	0.32

STOP BANG scores (a validated marker of the risk of OSA status) are not a strong predictor of postoperative desaturation.

Authors' contributions

Study design/planning: A.K.K., D.I.S., Z.S., J.Y., A.K., P.J.D., L.S.
Study conduct: A.K.K., D.I.S., A.J.N., B.D.H., A.K.
Data analysis: J.Y.
Writing paper: A.K.K., D.I.S., A.J.N., J.Y., B.D.H., A.K., P.J.D., L.S.
Revising paper: all authors

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

Declaration of interest

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