Obesity, epidural analgesia, and subcostal incision are risk factors for postoperative desaturation

L'obésité, l'analgésie péridurale et l'incision sous-costale sont des facteurs de risque de désaturation postopératoire

Arunotai Siriussawakul, MD · Sahatsa Mandee, MD · Jathuporn Thonsontia, MD ·
Piyasak Vitayaburananont, MD · Somsak Areewatana, MD · Jaruwan Laonarinthawoot, RN

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Abstract

Purpose This study was designed to determine the incidence of oxygen desaturation after upper abdominal surgery during the first 48 hr on general surgical wards and also to identify risk factors for oxygen desaturation.

Methods This descriptive study was conducted in 206 patients not expected to receive supplemental oxygen postoperatively who were undergoing upper abdominal surgery in a tertiary care university hospital. Desaturation was classified either as constant, i.e., oxygen saturation < 90% for > three minutes or < 85% once or as episodic, i.e., when oxygen saturation is decreased by $\geq 5\%$ below baseline for one to two minutes ten times or more during the night period. Possible risk factors were elderly patients (> 70 yr), obesity (body mass index [BMI] > 25 kg·m⁻²), smoking, surgical time > 180 min, postoperative pain control methods, intraoperative blood loss, and site of incision.

Results Of the 206 patients enrolled, 171 were retained for analysis. Desaturation occurred in 65 patients (38%). Forty-eight of these had constant hypoxemia with nadir oxygen saturation values ranging from 71–89%. The remaining 17 patients experienced nocturnal episodic

hypoxemia. After multivariate analysis, the three factors that correlated with postoperative desaturation were BMI > 25 (adjusted odds ratio [OR] 3.06; 95% confidence interval (CI) 1.38–6.79; $P = 0.006$), subcostal incision (OR 2.68; 95%CI 1.34–5.38; $P = 0.005$), and neuraxial opioids (OR 2.44; 95%CI 1.21–4.91; $P = 0.013$).

Conclusion Oxygen desaturation is common after upper abdominal surgery, and the risk factors are obesity, a subcostal incision, and neuraxial opioid administration.

Résumé

Objectif Cette étude a été conçue afin de déterminer l'incidence de désaturation en oxygène dans les 48 h après une chirurgie abdominale haute aux unités de soins de chirurgie générale ainsi que d'identifier les facteurs de risque associés à une désaturation en oxygène.

Méthode Cette étude descriptive a été menée auprès de 206 patients pour lesquels de l'oxygène supplémentaire n'était pas prévu après l'opération et qui subissaient une chirurgie abdominale haute dans un hôpital universitaire de soins tertiaires. La désaturation a été catégorisée en constante, soit une saturation d'oxygène < 90 % pour > trois minutes ou < 85 % une fois, ou épisodique quand la saturation d'oxygène a diminué de $\geq 5\%$ sous la valeur de base pour une ou deux minutes dix fois ou plus pendant la nuit. Les facteurs de risque possibles étaient l'âge (patients > 70 ans), l'obésité (indice de masse corporelle [IMC] > 25 kg·m⁻²), le tabagisme, une durée de chirurgie > 180 min, les méthodes de contrôle de la douleur postopératoire, les pertes de sang peropératoires et le site d'incision.

Résultats Sur les 206 patients inscrits à l'étude, 171 ont été retenus pour que leurs données soient analysées. Il y a eu désaturation chez 65 patients (38 %). Parmi eux, 48 présentaient une hypoxémie constante avec des valeurs minimales de saturation d'oxygène allant de 71 à 89 %.

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A. Siriussawakul, MD (✉) · S. Mandee, MD ·
J. Thonsontia, MD · P. Vitayaburananont, MD ·
S. Areewatana, MD

Department of Anesthesiology, Faculty of Medicine, Siriraj
Hospital, Mahidol University, Bangkok 10700, Thailand
e-mail: siasru@mahidol.ac.th

J. Laonarinthawoot, RN
Department of Surgery, Faculty of Medicine, Siriraj Hospital,
Mahidol University, Bangkok 10700, Thailand

Les 17 patients restants ont vécu des épisodes d'hypoxémie pendant la nuit. Après une analyse multivariée, les trois facteurs montrant une corrélation avec la désaturation postopératoire étaient un IMC > 25 (rapport de cotes [RC] ajusté 3,06; intervalle de confiance (IC) 95 % 1,38-6,79; $P = 0,006$), l'incision sous-costale (RC 2,68; IC 95 % 1,34-5,38; $P = 0,005$), et les opioïdes neuraxiaux (RC 2,44; IC 95 % 1,21-4,91; $P = 0,013$).

Conclusion *La désaturation en oxygène est un phénomène courant à la suite d'une chirurgie abdominale, et les facteurs de risque sont l'obésité, une incision sous-costale et l'administration d'opioïdes neuraxiaux.*

Arterial oxygen desaturation following upper abdominal surgery has been recognized for more than twenty years. Two types of desaturation are recognized. Constant desaturation lasts for a few minutes and has been attributed mainly to a decrease of functional residual capacity by atelectasis, microatelectasis, reduction of diaphragm and intercostal muscle activity, residual anesthetic drugs, and postoperative pain limiting deep breathing.¹⁻⁴ The second type of desaturation is episodic nocturnal desaturation that may be related to disruption of the normal sleep pattern induced by stress and the physiologic alterations due to anesthesia and surgery.^{5,6} Both conditions frequently occur on the second postoperative day and may last longer than one week postoperatively.^{2,6} Theoretically, improved surgical and anesthetic techniques and effective postoperative pain control could alleviate the causes of hypoventilation in the postoperative period.

In a recent meta-analysis, it was reported that the incidence of pulmonary complications in patients undergoing thoracic or abdominal surgery with systemic analgesia decreased from 34% to 12% in the period 1971 to 2006.⁷ Postoperative epidural analgesia improves pulmonary function and arterial oxygenation.⁷ Therefore, the incidence of postoperative desaturation, which has been reported as 30-50% in the past, might be less today.⁸⁻¹⁰ As a result, supplemental oxygen might be unnecessary on general surgical wards for selected patients who receive adequate postoperative pain control after upper abdominal procedures.

The purpose of this study was twofold: first, to estimate the incidence of desaturation postoperatively in the first 48 hr after upper abdominal surgery in patients cared for on general surgical wards and second, to determine the factors associated with postoperative hypoxemia.

Methods

This prospective observational study was approved by the Institutional Review Board, and informed consent was

obtained from all patients. The patients enrolled in the present study comprised adults who were undergoing upper abdominal procedures with subcostal and/or midline incision and were cared for on general surgical wards. Patients were excluded if they had any one of the following conditions: preoperative hypoxemia (oxygen saturation < 90%), documented chronic obstructive pulmonary disease, coronary artery disease, obstructive sleep apnea,¹¹ and factors interfering with proper use of a pulse oximeter.¹² In addition, patients were excluded from this study if they could not be weaned from supplemental oxygen at the time of discharge from the postanesthetic care unit (PACU).

Anesthetics, analgesics, and surgical techniques were at the discretion of the anesthesiologist and surgeon. Following surgery, all patients were transferred to the PACU and observed for one to two hours. Discharge from the PACU was based on achievement of an Aldrete Recovery Score ≥ 9 .¹³ Supplemental oxygen was discontinued for more than 15 min before discharge. If oxygen saturation was maintained at or above 95%, patients were transferred to the ward without supplemental oxygen. Postoperative pain was managed by the Acute Pain Service for the first 48-72 hr postoperatively. Bupivacaine 0.0625% and morphine 0.02 mg·mL⁻¹ or fentanyl 1-2 µg·mL⁻¹ were administered in patients with an epidural catheter. Intravenous morphine or fentanyl was used in the remaining patients either as a continuous infusion or as a patient-controlled analgesia (PCA). All medications were titrated to obtain a pain score ≤ 3 on the numerical pain score ranging from 0 to 10.

As soon as patients were transferred to the general surgical ward, oxygen saturation was measured using a continuous pulse oximeter via a finger probe (Philips Intellivue MP 40, Boeligen, Germany or Dash 4000, Waukesha, WI, USA). Starting from the third hour postoperatively, all oxygen saturation values were recorded and collected with computer software every minute until desaturation was detected or until 48 hr had passed. An alarm was preset to go off when oxygen saturation decreased to < 90%. The ward nurses checked for the proper placement of the finger probe every hour and whenever the pulse oximeter monitor sounded this alarm. Every eight hours, a research coordinator reviewed oxygen saturation values from the recorded data. As soon as desaturation was detected by a ward nurse or by a research coordinator, supplemental oxygen was administered in order to maintain the oxygen saturation at > 90%.

Constant desaturation, as defined by the Royal College of Anesthesiology of Thailand, is an oxygen saturation < 90% for > three minutes, or an oxygen saturation < 85% once. *Episodic* desaturation is defined as a decrease in oxygen saturation $\geq 5\%$ below baseline lasting from one to two minutes and occurring ten times or more during the night

period (from 23:00 to 7:00). This is a modification of the definition from Lewer *et al.*⁶ and Rosenberg *et al.*¹⁴

Demographic data, surgical procedures, site of operation, anesthetic and analgesic management, and intraoperative events were recorded. Possible risk factors for desaturation were the following: elderly¹⁵ (≥ 70 yr old), obesity (body mass index [BMI] $> 25 \text{ kg}\cdot\text{m}^{-2}$),¹⁶ smoking⁸ (> 20 packs per year), long surgical time (> 180 min), subcostal vs midline incision, epidural analgesia with opioids vs intravenous analgesia for postoperative pain control,^{17,18} and excessive bleeding. The estimated blood loss was calculated and reported as a percentage of blood volume according to the following formulae:

For males:

$$\% \text{ Blood loss} = \frac{\text{Blood loss (mL)} \times 100}{70 \times \text{Body weight (kg)}}$$

For females:

$$\% \text{ Blood loss} = \frac{\text{Blood loss (mL)} \times 100}{65 \times \text{Body weight (kg)}}$$

Statistical analysis

The primary objective of the study was to estimate the incidence of desaturation. Sample size calculation was based on an expected incidence of desaturation of 40% derived from a 30–50% incidence in previous studies.^{8–10} To obtain a 95% confidence interval (CI) of 7%, a sample of 189 subjects was required. Regarding the secondary objective, it was anticipated that there would be seven factors associated with desaturation: age ≥ 70 yr, obesity, heavy smoker, subcostal incision, neuraxial opioid for postoperative pain control, greater operative time, and intraoperative blood loss. The sample size estimation was based on the current recommendation among statisticians for multiple logistic regression analysis, i.e., that the number of subjects with desaturation be five to ten times the number of risk factors in the multiple logistic model.¹⁹ Therefore, approximately 70 subjects with desaturation were needed. Using the previous sample size calculation of 189 and 40% incidence, there would be about 75 patients with desaturation. Thus, the sample size of 189 would be adequate for both objectives of this study.

Descriptive statistics were used to examine clinical characteristics, perioperative variables, and incidence of desaturation. For univariate analysis, the Chi square test or Fisher's exact test was used to examine all categorical risk factors. The Mann Whitney U test was used to examine estimated blood loss, which was continuous data. Factors with $P < 0.20$ from univariate analysis were then entered into a multiple logistic regression model of desaturation. Statistical analysis was conducted using the software

program, SPSS version 11.5 Inc., Chicago, IL, USA. Data are presented as mean $\pm$ standard deviation (SD) (range), median (Min, Max), number (percent), or adjusted odds ratios (95%CI) as appropriate. $P < 0.05$ was considered to indicate statistically significant differences.

Results

A total of 206 patients were enrolled in the study. However, 17 patients were excluded because supplemental oxygen could not be weaned in the PACU. Within two hours postoperatively, 189 patients were transferred to a general surgical ward without supplemental oxygen. Subsequently, 18 cases were excluded from the study during the first 24 hr postoperatively because oxygen was administered without defined desaturation (Figure 1). Among these 18 patients, 14 patients experienced tachypnea, one - tachycardia, one - hypotension, and one - anemia. The remaining patient developed dyspnea because of abdominal distension and intra-abdominal bleeding, and subsequently underwent re-exploration. Data from the remaining 171 patients were included in the final analysis. No patient was diagnosed with myocardial infarction or cerebrovascular accident during the time of observation. The perioperative characteristics of these patients are described in Table 1.

Overall, desaturation occurred in 65 patients (38%). Forty-eight of these patients had constant hypoxemia with oxygen saturation nadirs ranging from 71–89%, with the majority occurring at or near the third postoperative hour (Figure 2). The remaining 17 patients experienced nocturnal episodic hypoxemia. A physician in charge at the time was notified as soon as desaturation was detected, and patients were treated with oxygen by nasal cannula or oxygen mask to keep saturation $> 90\%$. The patients were assigned to the desaturation group and were discontinued from the study.

Factors associated with desaturation (Tables 2 and 3)

On univariate analysis, six factors associated with desaturation were found to be statistically significant: BMI $> 25 \text{ kg}\cdot\text{m}^{-2}$, subcostal incision, use of neuraxial opioid for postoperative pain control, significant intraoperative blood loss, age ≥ 70 yr, and surgical time > 180 min (Table 2). With multiple logistic regression, only three of these factors were found to be independently related to desaturation: a BMI $> 25 \text{ kg}\cdot\text{m}^{-2}$, a subcostal incision, and the use of neuraxial opioids.

Fig. 1 Enrolment of study participants

Discussion

This study provides an estimate of the incidence of desaturation in patients undergoing upper abdominal surgery. The study's main finding in this group of patients is 1) Constant desaturation was common near the third hour postoperatively; 2) Although high-risk patients were excluded from the study, severe constant hypoxemia was not rare and could occur at any point during 48 hr postoperatively; 3) Compared with 25-48 hr postoperatively, both constant and episodic desaturation occurred more frequently during the first 24 hr; and 4) BMI > 25 kg·m⁻², subcostal incision, and neuraxial opioid for postoperative pain control were independent predictors of desaturation.

Hypoxemia after upper abdominal surgery causes major complications of many organ systems. In the case of the cardiovascular system, these include hypertension, tachycardia, cardiac arrhythmia, and ST segment changes (which may be related to ten or more incidents of episodic nocturnal hypoxemia).^{20,21} As for the central nervous system, complications include delirium, personality changes, and memory changes. These conditions frequently occur on the third postoperative day, which may be due to the occurrence of desaturation on the preceding night.^{15,22}

Additional complications arising from arterial hypoxemia may be decreased tissue oxygenation resulting in an increased risk of infection and delayed wound healing.^{18,20} Finally, arterial hypoxemia results in patients attempting to compensate by increasing their respiratory rate and their effort to breathe. Respiratory failure may result if these conditions are not treated.^{18,20}

Our hospital is a university hospital and tertiary care centre that has a monthly average of 30 to 40 patients undergoing upper abdominal surgery. With thorough pre-operative preparation, the use of modern surgical techniques and anesthesia, and adequate postoperative pain control, most patients can be transferred to general surgical wards for postoperative recovery within two hours after surgery. Even after major operations, such as hepatectomy, pancreatectomy or Whipple's operation, patients receive supplemental oxygen on general surgical wards only when they have coexisting diseases, such as coronary heart disease and pulmonary disease, or if they have respiratory difficulties detected clinically. This approach is possible because the use of effective pain control methods in our hospital encourages patients to do deep breathing exercises immediately after being transferred back to surgical wards. As a result, the attending medical personnel believe there

Table 1 Perioperative clinical characteristics of 171 patients

Variables	Mean $\pm$ SD or number (%) ($n = 171$)
Age (yr)	54 $\pm$ 14.31
Male gender	93 (54%)
ASA Classification	
I	27 (15.8)
II	112 (65.5)
III	32 (18.7)
Body mass index ($\text{kg}\cdot\text{m}^{-2}$)	22.4 (3.9)
Smoke status (packs per yr)	5.8 (11.5)
Preoperative oxygen saturation (%)	97.9 (1.8)
Type of operation	
Hepato-biliary-pancreas	90 (52.6)
Stomach-bowel	67 (39.2)
Urology, gynecology	14 (8.2)
Site of operation	
Subcostal incision	85 (49.7)
Upper midline $\pm$ lower midline incision	86 (50.3)
Choice of anesthesia	
General anesthesia	72 (42.1)
Combined general and epidural anesthesia	99 (57.9)
Intraoperative hypotension and received vasopressor	71 (41.5)
Intraoperative blood transfusion	18 (10.5)
Duration of surgery (min)	166.2 $\pm$ 93.5
Last recorded before discharge from Recovery Room	
Oxygen saturation on room air (%)	97.2 $\pm$ 0.8
Post anesthetic Aldrete Recovery Score	9.45 $\pm$ 0.5
Postoperative pain control methods	
Continuous intravenous opioid, patient-controlled analgesia	89 (52.1)
Neuraxial opioid and bupivacaine	82 (47.9)
Averaged pain score during observation period	3.9 (2.4)

SD = standard deviation

Fig. 2 Lowest saturation value in patients with constant desaturation as a function of the postoperative hour where the event occurred. One dot represents one patient

will be a lower incidence of postoperative hypoxemia from hypoventilation than in the past. Another reason for this approach is the fact that general surgical wards in our country normally have a high patient to nurse ratio but a shortage of pulse oximeters, oxygen pipelines, and related equipment. Administration of oxygen to all patients who have undergone upper abdominal surgical procedures but who are stable is controversial and its cost effectiveness is uncertain. Nowadays, most surgical teams realize the need for oxygen administration in the acute perioperative periods regardless of venue. In comparison, staff members caring for patients on a general surgical ward generally care for patients with low to moderate risk. Administration of oxygen is not standard treatment unless patients have pre-existing diseases or abnormal conditions.

However, the incidence of postoperative hypoxemia reported in previous studies ranges from 30-50%,⁸⁻¹⁰ with

Table 2 Factors associated with postoperative hypoxemia: univariate analysis

Factors	Number (%)		OR (95%CI)	Pvalue
	Desaturation (n = 65)	No desaturation (n = 106)		
Age (yr)				
< 70	51 (35.4)	93 (64.6)	1	-
≥ 70	14 (51.9)	13 (48.1)	1.96(0.86,4.50)	0.106
BMI (kg·m ⁻²)				
≤ 25	41 (31.5)	89 (68.5)	1	-
> 25	24 (58.5)	17 (41.5)	3.07 (1.49,6.32)	0.002
Smoking (packs per yr)				
≤ 20	59 (36.9)	101 (63.1)	1	
> 20	6 (54.5)	5 (45.5)	2.05 (0.60,7.03)	0.336
Incision				
Midline incision	23 (26.7)	63 (73.3)	1	-
Subcostal incision	42 (49.4)	43 (50.6)	2.68 (1.41,5.07)	0.002
Postoperative pain control methods				
Intravenous opioid	22 (27.5)	58 (72.5)	1	-
Neuraxial opioid	43 (47.8)	47 (52.2)	2.41 (1.27,4.58)	0.007
Surgical time (min)				
≤ 180	38 (33.9)	74 (66.1)	1	-
> 180	27 (45.8)	32 (54.2)	1.64 (0.86,3.13)	0.13
Estimated blood loss*				
%, Median (Min, Max)	8.3 (0.12, 66.67)	4.6 (0.27, 68)	-	0.005

* % Blood loss relative to blood volume:

$$\text{Male} = \frac{\text{Blood loss (mL)} \times 100}{70 \times \text{Bodyweight (kg)}}$$

$$\text{Female} = \frac{\text{Blood loss (mL)} \times 100}{65 \times \text{Bodyweight (kg)}}$$

BMI = body mass index; OR = odds ratio; CI = confidence interval

Table 3 Results of multiple logistic regression analysis of postoperative hypoxemia

Factors	Adjusted OR (95%CI)	P value
BMI > 25 kg·m ⁻²	3.06 (1.38, 6.79)	0.006
Subcostal incision	2.68 (1.34, 5.38)	0.005
Neuraxial opioid for postoperative pain control	2.44 (1.21, 4.91)	0.013
Log 10 blood loss	1.75 (0.83,3.68)	0.14
Age ≥ 70 yr	2.30 (0.90, 5.90)	0.08
Surgical time > 180 minutes	1.12 (0.51, 2.47)	0.78

OR = odds ratio;
CI = confidence interval;
BMI = body mass index

the highest incidence of early hypoxemia occurring in the PACU,¹⁷ and the incidence of late arterial hypoxemia peaks on the second postoperative day.^{5,6} In this study, we used three definitions to determine desaturation. The incidence of desaturation (38%) found in the present study was not clearly less than in studies performed in the last decade, even though we excluded high-risk patients, provided modern surgical and anesthetic management, and encouraged patients to do deep breathing exercises immediately after recovery from anesthesia. Constant hypoxemia was observed chiefly in the first seven postoperative hours, but severe hypoxemia (oxygen saturation < 85%) occurred in some patients after 40 hr postoperatively. Reduction of

functional residual capacity causes early postoperative hypoxemia, as the combined effect of pain from the incision and temporary diaphragm dysfunction.^{1-4,23} Currently, there is no standard definition regarding episodic hypoxemia. We modified the definition from Rosenberg *et al.* based on their experiment which presented that ten times episodic desaturation is related to ST abnormality.¹⁴ In our study, 17 patients were found to have episodic desaturation, and 14 of these patients experienced desaturation on their first night postoperatively.

As for secondary outcomes, we dichotomized each possible risk factor into two groups. Obesity (defined by BMI > 25 kg·m⁻²), subcostal incision, and neuraxial

opioid administration for postoperative pain control were identified as independent and significant predictors of desaturation. Obesity and subcostal incision were shown to be risk factors in many previous reports. In contrast, there was some debate in those reports as to whether neuraxial opioid administration for postoperative pain control caused postoperative hypoxemia. Opioids cause hypoventilation and decrease ventilatory response to both hypercarbia and hypoxia. Even when PCA, the safest method, is used, it has been reported that 28 of 32 patients experienced mild to moderate desaturation on the second postoperative day.²⁴ Due to the low dosage of morphine administered, it was believed that neuraxial opioid administration for postoperative control could solve this problem while providing effective pain control. Rosenberg *et al.* proved this belief wasn't true. They authored a number of publications on the effects of opioid suppression of rapid eye movement (REM) sleep with subsequent REM rebound with episodic hypoxemia and suspected complications.^{10,21,25} Furthermore, after 25 patients underwent elective coronary bypass graft surgery combined with thoracic epidural analgesia, Lundstrom *et al.* noted all of them experiencing episodic desaturation, while 16 of 21 patients who received conventional intravenous analgesia experienced episodic hypoxemia on the third postoperative night.²⁶ This study identified that 17 of 171 patients (10%) experienced episodic hypoxemia, which is similar to Rosenberg's and Lundstrom's findings.

There are several limitations to this study. First, two risk factors identified as being significant in other published papers, namely, age ≥ 70 yr and smoking > 20 packs per year, were not significant in this study. This may be because the sample size (27 and 11, respectively) was too small. A larger sample size is difficult to obtain at our hospital because patients in these two groups usually have coexisting diseases requiring them to be transferred to the high dependency unit or the intensive care unit rather than to general surgical wards. Additionally, the incidence of episodic hypoxemia was low compared with the incidence in other papers. It is possible that some data were not recorded in this study because of limitations of the pulse oximeter equipment that was used, which restricted data recording to once per minute. However, either more sophisticated data recording equipment or continual visual monitoring was employed in the other studies, which would ensure all data were captured.

In conclusion, the incidence of desaturation in this study was 38%, and the risk factors were BMI > 25 , subcostal incision, and neuraxial opioid administration for postoperative pain control. Based on our findings, pulse oximeters should be available for added vigilance, and supplemental oxygen should be given to patients after upper abdominal surgery for 48 hr postoperatively.

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