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Hypoxemia in the Postanesthesia Care Unit: An Observer Study

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To determine the incidence and duration of hypoxemia in the postanesthesia care unit (PACU), 200 patients were investigated in a single-blind observer study. The number of unrecognized hypoxemic episodes, as well as risk factors and possible association between hypoxemia and postoperative morbidity, were studied. Oxygenation was monitored continuously with a pulse oximeter. One or more hypoxemic episodes ($Sp_{O_2} \leq 90\%$) were noted in 55% of the patients. Sp_{O_2} values ≤ 80% were noted in 13% of the patients. Supplementary oxygen was given during 55% of the 447 hypoxemic episodes registered. The hypoxemic episodes were unrecognized by the staff in 95% of the cases. With stepwise multiple logistic regression analyses, risk factors associated with a higher incidence of hypoxemia were: duration of anesthesia ($P < 0.0001$), age ($P < 0.002$) and a history of smoking ($P < 0.01$). Patients who had undergone regional anesthesia had a lower risk of hypoxemia ($P < 0.0002$). The occurrence of hypoxemia in the PACU could not be correlated to postoperative morbidity. We conclude that hypoxemic episodes in our PACU are common and that the routine use of supplemental oxygen combined with normal clinical surveillance did not prevent hypoxemic episodes. (Key words: Hypoxemia: postoperative, supplemental oxygen. Anesthesia: Complications, risk factors, regional. Monitoring: Pulse oximetry, oxygen saturation.)

STUDIES of adverse anesthetic outcome indicate that hypoxemia often is a major contributing factor.[1–4] The occurrence of postoperative hypoxemia has been documented in several studies.[5–7] In the majority of these, arterial blood samples were drawn at various time intervals. The introduction of pulse oximetry has made it possible to investigate postoperative hypoxemia with a continuous measuring technique. Morris *et al.*[8] used a pulse oximeter to estimate hypoxemia in the recovery room, but it was not used continuously.

The aim of this single-blind observer study was to investigate, under routine conditions and with continuous measuring, the incidence, degree, and duration of hypoxemia in a postanesthesia care unit (PACU), and to determine the number of unrecognized hypoxemic episodes. We also looked for risk factors, possible causes of hypoxemia, and an association between hypoxemia and postoperative complications.

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Materials and Methods

The protocol was approved by the Regional Ethics Committee for Copenhagen, and the patients gave their informed consent. In our study we defined oxyhemoglobin saturation (Sp_{O_2}) ≤90% as mild hypoxemia, ≤85% as moderate hypoxemia, and ≤80% as severe hypoxemia.

Routine PACU care was not altered. Upon admission to the PACU, all patients received at least 3 l/min nasal oxygen, which was continued until 15–30 min before discharge. During transportation to the PACU, oxygen was not administered. The patients were monitored in our usual manner with measurements of blood pressure and pulse rate at least every 15 min, and when indicated by type of surgery and the patients physical conditions, continuous electrocardiography (ECG).

Five pulse oximeters (Ohmeda, model 3700®) were installed in the PACU. Data from all oximeters were either recorded on strip-chart recorders, or stored for further analysis on a Olivetti M 24 computer.

Candidates for the study were patients aged 18 yr or more and who had undergone elective operations under general, spinal, or epidural anesthesia lasting more than 20 min. Patients admitted to the PACU had undergone orthopedic, gastroenterologic, urologic, or gynecologic operations. Excluded from the study were patients with a history of severe lung disease and preoperative $Sp_{O_2} \leq 90\%$.

During the study period (August 1–30, 1988), 202 patients fulfilled the inclusion criteria. Two patients were excluded because they were transferred to the intensive care unit immediately after surgery. Observation and monitoring started immediately upon arrival in the PACU and continued until discharge. The probe of the pulse oximeter was applied to an index finger of the hand opposite to the blood pressure cuff, within 15 s from arrival in the PACU. The observers, a research fellow and a specially trained medical student, monitored oxygenation with the pulse oximeter continuously. The display of the pulse oximeter was shielded from the PACU staff, and the alarms were disabled to secure blindness of the study.

If the pulse oximeter showed $Sp_{O_2} \leq 90\%$ for more than 20 s, the observer recorded the data and the circumstances. If Sp_{O_2} was ≤ 85% for more than 3 min or decreased to ≤ 80%, the observer notified the PACU staff, and the circumstances and the ensuing interventions were recorded. At discharge from the PACU, the staff were notified if the Sp_{O_2} was ≤ 90%, and supplementary oxygen was prescribed on the ward.

Sp_{O_2} data were accepted only if a normal plethysmographic pulse waveform was present on the display of the pulse oximeter. For every patient, the degree of hypoxemia and duration of events was later confirmed by review of the strip chart or computer recordings.

Each patient's age, body habitus, ASA physical status, cardiopulmonary or other co-existing diseases, smoking history, anesthetic technique and duration, surgical site, and size, were noted. Body habitus was classified by comparing patient weight and height with ideal body weight and height. A weight of 120% of the norm was classified as obesity.[9] The medical records were reviewed for a history of respiratory disease, heart disease, or hypertension. The operations were divided into major surgery (cholecystectomy, colectomy, nephrectomy, or major bone surgery) and minor surgery (herniotomy, laparoscopy, or minor limb surgery).

The anesthetic technique was divided into two main groups, general anesthesia and regional anesthesia. Independently of the study, the physicians caring for each patient chose the anesthetic technique, taking into consideration: 1) the type of operation, 2) the patient's physical status, and 3) the patient's wishes. Patients receiving beta-adrenergic blocking agents for treatment of hypertension and those with with suspected pulmonary hypertension were not given spinal anesthesia. Patients with chronic obstructive lung disease or asthma were urged to accept regional anesthesia.

For preanesthetic medication the patients received diazepam orally or meperidine intramuscularly 1 h prior to induction (table 1). General anesthesia included one of our two standard techniques: 1) potent inhalation agent (enflurane, isoflurane, or halothane), nitrous oxide/oxygen, and fentanyl, or 2) intravenous anesthesia with nitrous oxide/oxygen (table 1). Induction of anesthesia was in all patients performed with thiopental 2–5 mg/kg. For neuromuscular blockade, pancuronium or atracurium were used. Neuromuscular blockade was reversed with 2.5 mg neostigmine and 1.0 mg atropine at the end of the operation. Regional anesthesia was either epidural or spinal anesthesia. In the PACU, morphine was administered as the analgesic, intravenously, intramuscularly, or epidurally. The individual bolus doses of morphine never exceeded 5 mg intravenously and 10 mg intramuscularly.

The anesthetist caring for the patient during the stay in the operating room (OR) was instructed to follow the department's normal guidelines for patient care and safety. Patients receiving neuromuscular blocking agents

TABLE 1. Demographic Data, Duration of Anesthesia, Duration of Stay in the PACU, and Amout of Drugs Used for Preanesthetic Medication, Anesthesia, and Analgesia in the PACU

	Number of Patients (n = 200)	Mean	Median	Range
Demographics				
Age		54	58	18–86
Weight (kg)		71	68	40–123
Height (cm)		169	168	150–195
Duration of anesthesia (min)		114	115	20–270
Duration of stay in PACU (min)		139	130	35–360
Preanesthetic medication				
Diazepam (mg)	188	11.6	10	5–20
Meperidine (mg)	7	64	75	50–75
Regional anesthesia	38			
Fentanyl (mg)	9	0.09	0.1	0.05–0.1
Midazolam (mg)	17	5.1	5	2–12
Diazepam (mg)	4	6	6	2–10
General anesthesia	162			
Intravenous	114			
Fentanyl (mg)	114	0.41	0.4	0.05–1.2
Droperidol (mg)	78	9.7	10	1.2–17.5
Midazolam (mg)	22	6.2	5	2–15
Diazepam (mg)	9	6.7	5	5–15
Inhalation	48			
Fentanyl (mg)	48	0.36	0.27	0.1–1.0
Relaxation	129			
Pancuronium (mg)	76	6.3	6	2.7–15
Atracurium (mg)	53	31.5	30	10–60
Analgesia in the PACU	110			
Morphine (im or iv) (mg)	101	12.3	10	2.5–30
Morphine (epidural) (mg)	8	3.5	4	1–8
NSAID (mg)	50	1040	1000	1000–2000

were monitored intraoperatively with a nerve stimulator (Biometer®) with the use of tactile evaluation of the train-of-four stimulation pattern. Patients were not transported from the OR to the PACU until their vital signs were stable and they could respond to commands.

Postoperative complications were extracted from the discharge notes.

All data were coded and were checked for missing or inconsistent values. After input into a database system, the data for each patient were checked against the original datasheet. The incidence of hypoxemia during the stay in the PACU is reported as a percentage. The Sp_{O_2} values and the duration of hypoxemia are reported as mean, median, and range.

For each risk factor, a chi-squared test was used to compare the proportion of patients who had at least one hypoxemic episode to those who did not. To account for the inexclusivity of the risk factors and to eliminate errors due to multiple comparisons, we used stepwise multiple logistic regression analyses to separate the roles of the different risk factors. These analyses were performed only at the first hypoxemia level, $Sp_{O_2} \leq 90\%$. The computer analyses were conducted with the SCIBAS system as described by Mortensen and Larsen.[10]

Of postoperative complications, the proportion associated and not associated with hypoxemic episodes was compared. The chi-squared test was used to calculate the possibility that the proportion did not differ.

A value of $P < 0.05$ was considered statistically significant.

Results

Two hundred patients, 118 female and 82 male, were studied. Table 1 presents the demographic data, duration of anesthesia, duration of stay in the PACU, premedication, anesthetics, and postoperative analgesics received.

In seven patients (3.5%), postoperative monitoring with the pulse oximeter was periodically abandoned because of lack of cooperation from the patient or low peripheral perfusion. In 11.5% of the patients, the observers noted artifact with no clinical significance, such as brief motion artifact.

One or more mild hypoxemic episodes were noted in 111 patients (55%) during the PACU stay. In 28% of the patients, $Sp_{O_2} \leq 85\%$ was noted in one or more episodes, and values $\leq 80\%$ were noted in 13% of the patients (table 2). When arriving in the PACU before supplemental oxygen had been initiated, 32% of the patients had $Sp_{O_2} \leq 90\%$; mean Sp_{O_2} was 84%, median 86%, and range 50–90%. At discharge from the PACU after supplemental oxygen had been terminated, 22% of the patients had $Sp_{O_2} \leq 90\%$; mean Sp_{O_2} was 87.5%, median 88%, and range 85–90%.

The number of hypoxic episodes totaled 447 (table 2); 69% of the hypoxemic patients had more than 1 hypoxemic episode; and 22% of these had more than 5. The duration of hypoxemic episodes were up to 80 min (mean 3.9 min) (table 2).

Of the hypoxemic episodes, 55% (corresponding to 32% of the patients) occurred during oxygen administration. The remaining hypoxemic episodes occurred when the patients did not receive supplemental oxygen—22% just before leaving the PACU, 15% upon admission to the PACU, and 8% when oxygen administration was accidentally discontinued.

In 5% of the hypoxemic episodes, the staff recognized the event spontaneously and intervened. The observer notified the staff in accordance with the study protocol in 15% of the hypoxemic episodes. In the remaining 80% of the episodes, the event was not recognized by the staff and no intervention was made by the observers. In the 20% of episodes in which interventions were made, increased flow of oxygen, readministration of oxygen, and ordering of oxygen on the ward accounted for 75% of the interventions (table 3).

Several significant patient-related and operative risk factors were discovered through the chi-squared test (tables 4 and 5). When applying the stepwise multiple logistic regression analyses, the following risk factors were identified: duration of anesthesia ($P < 0.0001$), anesthetic technique ($P < 0.0002$), age ($P < 0.002$), and smoking ($P < 0.01$).

TABLE 2. Number of Patients with One or More Episodes of Hypoxemia and Number and Duration of Hypoxic Episodes at Each Saturation Level

Sp_{O_2} (%)	Number of Patients (n = 200)	(%)	Number of Hypoxic Episodes	Number of Hypoxic Episodes per Patient			Duration of Hypoxic Episodes		
				Mean	Median	Range	Mean (s)	Median (s)	Range (s)
≤90	111	55	447	4.4	3	1–24	231	72	20–4800
≤85	56*	28	92	1.6	1	1–6	166	60	10–2820
≤80	26*	13	30	1.2	1	1–3	126	60	10–999

* The 56 patients with $Sp_{O_2} \leq 85\%$ and the 26 with $Sp_{O_2} \leq 80\%$ are also counted among the 111 with $Sp_{O_2} \leq 90\%$.

TABLE 3. Interventions by the PACU Staff

Intervention	n	%
Increased O_2 flow	73	44
Airway adjustment	16	9
Change from nasal cannula to face mask	17	10
Readministration of O_2 in the PACU	13	8
Ordering of supplemental O_2 on the ward	38	23
Fluid administration	1	0.5
Injection of doxapram	7	4
Injection of naloxone	2	1
Injection of flumazenil	1	0.5
Total	168	100

In some instances more than one intervention occurred.

The observers were not able to find an obvious reason for 76% of the 447 hypoxemic episodes. In the remaining 24% of the hypoxemic episodes, the following causes were noted: airway obstruction, 8%; horizontal position combined with obesity, 15%; and hemodynamic instability, 1%.

In 13 patients (6%), postoperative complications, such as wound infection, pneumonia, cystitis, and thromboembolic complications, were recorded. There was no correlation between hypoxemic episodes in the PACU and the occurrence of these postoperative complications.

Discussion

In this study we found a high incidence of mild (55%) and severe (13%) hypoxemic episodes in 200 patients. Among these hypoxemic episodes, 55% occurred despite oxygen supplementation, and 95% were unrecognized by the staff. However, the occurrence of hypoxemia in the PACU could not be correlated with postoperative morbidity.

In previous studies of early hypoxemia with sampling of arterial blood after anesthesia, the incidence of hypoxemia was not stated, but a significant decrease in postoperative arterial oxygen tension (Pa_{O_2}) was found.[5–7] In the study by Morris *et al.*[8] in which a pulse oximeter was used, only 14% of patients experienced mild hypoxemic

TABLE 4. Patient-Related Risk Factors for Hypoxemia in the PACU

	Total Number of Patients	$Sp_{O_2} \leq 90\%$ (% of Patients)	P*	P†	$Sp_{O_2} \leq 85\%$‡ (% of Patients)	$Sp_{O_2} \leq 80\%$‡ (% of Patients)
Heart disease						
Yes	17	82	0.02	NS	41	18
No	183	53			27	13
Lung disease						
Yes	26	70	0.12	NS	34	15
No	174	53			27	12
Hypertension						
Yes	21	71	0.11	NS	38	24
No	179	54			27	12
Diabetes mellitus						
Yes	11	91	0.04	NS	55	36
No	189	53			26	12
Obesity						
Yes	59	61	0.17	NS	34	15
No	141	52			26	12
ASA physical status						
1	128	51	0.28	NS	24	10
2	44	64			36	18
3	24	63			33	12
4	4	75			25	25
Age (yr)						
≤29	24	25	0.01	0.002	17	4
30–39	21	38			19	14
40–49	36	61			28	8
50–59	29	52			17	7
60–69	40	63			35	18
70–79	43	70			37	19
≥80	7	72			43	29
Smoking						
Yes	76	65	0.02	0.01	38	17
No	123	48			22	11

* Chi-square test at the $Sp_{O_2} \leq 90\%$ level.

† Step-wise multiple logistic regression analyses at the $Sp_{O_2} \leq 90\%$ level to control for multiple comparisons and for the inexclusivity of the risk factors.

‡ Statistics not performed because of the relatively low number of patients at this level.

TABLE 5. Operative Risk Factors for Hypoxemia in the PACU

	Total Number of Patients	$Sp_{O_2} \leq 90\%$ (% of Patients)	P*	P†	$Sp_{O_2} \leq 85\%$‡ (% of Patients)	$Sp_{O_2} \leq 80\%$‡ (% of Patients)
Duration of anesthesia (min)						
≤60	37	19	0.00001	0.0001	11	8
61–120	82	57			26	7
≥121	81	70			38	21
Operation site						
Extremity	71	62	0.02	NS	35	15
Upper abdomen	22	82			46	36
Lower abdomen	93	48			22	8
Others	14	36			7	0
Operation size						
Major	100	70	0.001	NS	37	20
Minor	93	45			20	7
Diagnostic	7	43			28	0
Anesthetic technique						
Regional	38	29	0.002	0.0002	16	5
General	162	62			32	15
Relaxation (n = 162)						
Only Suxamethon for intubation	39	46	0.005	NS	18	5
Pancuronium	75	75			45	25
Atracurium	48	50			19	6

* Chi-squared test at the $Sp_{O_2} \leq 90\%$ level.

† Step-wise multiple logistic regression analyses at the $Sp_{O_2} \leq 90\%$ level to control for multiple comparisons and for the inexclusivity of the risk factors.

‡ Statistics not performed because of the relatively low number of patients at this level.

episodes. Since the monitoring in the latter study was discontinuous—Sp_{O_2} was measured 5 min after arrival in the PACU, 30 min later, and just before discharge—we believe the difference between our results and theirs can be explained by the difference in monitoring techniques. In our study, the incidence of hypoxemia at arrival in the PACU was 32%, which is in good agreement with other observer studies that used pulse oximetry during transportation from the OR to the PACU.[11,12] The high incidence of unrecognized hypoxemia at discharge from the PACU agrees with a study by Fromme *et al.*,[13] who, in an observer study with pulse oximetry during transportation from the PACU to the ward, found that 27% of patients suffered unrecognized oxyhemoglobin desaturation ($Sp_{O_2} \leq 90\%$). It seems that the stay in the PACU also could be accompanied by frequent episodes of hypoxemia, even during established oxygen supplemental.

Of the 447 hypoxemic episodes, 95% were unrecognized by the staff. This corresponds well with findings made as early as 1947, by Comroe and Botelho,[14] who stated that "serious grade of arterial anoxemia may be unrecognized by many physicians." In recent years, this conclusion has been supported in several studies that indicate that cyanosis and other clinical signs of hypoxemia are unreliable.[15] The pulse oximeter has been found accurate in the range of Sp_{O_2} 75–100% in several correlation studies.[16,17]

The risk factors for desaturation discovered in the current study agree with previous findings.[7,8,18,19] Several risk factors were discovered through chi-squared test. In a stepwise multiple logistic regression analyses, however, only duration of anesthesia, age, anesthetic technique, and smoking proved to be significant (tables 4 and 5). Patients who had undergone regional anesthesia had a much lower risk of hypoxemic episodes in the PACU ($P < 0.0002$), but even young, healthy patients undergoing short procedures experienced a relatively high incidence of hypoxemic episodes (25%). In 15% of episodes, the hypoxemia was attributed to obesity combined with horizontal position. In only 24% of the hypoxemic episodes did the clinical observers attribute hypoxemia to identifiable causes. This suggests that in many instances hypoxemia is the result of multiple and co-existing causes, including drug overdose, residual effects of neuromuscular blocking drugs, ventilation perfusion maldistribution, airway closure, diffusion hypoxemia, posthyperventilation hypoxia, and increased oxygen consumption.[7,18–24] The current study was not designed to isolate these factors.

We were unable to find any correlation between hypoxemic episodes in the PACU and the occurrence of postoperative complications. This lack of correlation is due probably to the relatively small number of patients studied. Another reason may be that this study did not investigate subtle changes in postoperative outcome. A third reason for this lack of correlation may be that some of the patients with postoperative complications had experienced far more numerous and more severe hypoxemic episodes during the anesthetic period. Moller *et al.*[25] found

in an observer study of design similar to the current one that during anesthesia, 55% of patients had mild and 19% had severe hypoxemic episodes. With this in mind, we still find it not unreasonable to assume that a correlation may exist between hypoxemia and the occurrence of postoperative complications, but more rigorous, large-scale studies are needed to evaluate this problem.

Pulse oximetry used during and after anesthesia has not yet been tested in clinical trials evaluating outcome. Cooper *et al.*[26] evaluated the effect of pulse oximetry on the rate and severity of anesthesia-related problems encountered in the OR and PACU. Significantly fewer events were recorded when pulse oximetry was used, but because of confounding factors, it was not possible to make a definitive conclusion.[26] Furthermore, the study did not examine outcome beyond the PACU.

The finding in the current study of a high number of unrecognized hypoxemic episodes in patients receiving oxygen supplement could lead to the conclusion that every patient in PACU should be monitored continuously with a pulse oximeter. It is known from an observer study with pulse oximetry during anesthesia in children that the use of this monitoring technique can reduce the number of hypoxemic episodes.[15] However, scientific evidence that demonstrates a correlation between postoperative hypoxemia and the occurrence of morbidity still is lacking. We do not know the level at which hypoxemia is damaging to the brain or other tissue, but it depends probably on such factors as age, co-existing illness, cerebral blood flow, and duration of hypoxemia.

Results from this study suggest that after routine anesthesia, hypoxemia is more common and severe than previously assumed. The routine use of supplemental oxygen combined with normal clinical surveillance is not sufficient to prevent hypoxemia. However, routine use of pulse oximetry in the PACU can be recommended only if further studies can prove that the use of this equipment will reduce postoperative morbidity.

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