THE PREVALENCE OF HYPOXEMIA DETECTED BY PULSE OXIMETRY DURING RECOVERY FROM ANESTHESIA

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Morris RW, Buschman A, Warren DL, Philip JH, Raemer DB. The prevalence of hypoxemia detected by pulse oximetry during recovery from anesthesia.

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ABSTRACT. Pulse oximetry was used to assess the prevalence of hypoxemia (arterial oxygen saturation of 90% or less) at various times in the immediate postoperative period: five minutes after arrival, 30 minutes later, and just before discharge. Among 149 inpatients studied, one or more hypoxemic measurements were made in 21 (14%) during their postoperative course. Of 92 outpatients, 1 (1%) was found to be hypoxemic. For inpatients, the prevalence of hypoxemia preoperatively, 5 minutes after arrival in recovery, 30 minutes later, and at discharge was 2%, 4%, 6%, and 9%, respectively. Patient factors associated with a significantly higher prevalence of hypoxemia were obesity (22%), body cavity surgical procedures (24%), age over 40 years (18%), American Society of Anesthesiologists physical status (I, 7%; II, 17%; III, 18%; IV, 100%), duration of anesthesia longer than 90 minutes (18%), and intraoperative administration of greater than 1,500 ml of fluid (20%). Unrecognized hypoxemia in postsurgical inpatients with or without these risk factors is common. Therefore routine monitoring of these patients with a pulse oximeter is suggested.

KEY WORDS. Complications: hypoxemia. Monitoring: oxygen. Measurement techniques: pulse oximetry. Anesthesia: postoperative period.

Inadequate oxygenation during the immediate postoperative period is usually assessed by clinical observation. However, inadequate oxygenation may not always be clinically evident, and direct monitoring of arterial oxygen saturation (SaO_2) may be indicated.

Hypoxemia (SaO_2 of 90% or less) has been documented in the operating room [1], during transport to the recovery room [2], and in the immediate postoperative period in children [3]. However, the incidence during recovery from anesthesia in adults has not been determined. The present study was designed to measure the prevalence of hypoxemia in postsurgical inpatients and outpatients. (Incidence is defined as the frequency of occurrence of any event or condition, e.g., hypoxemia, over a period of time and in relation to the population in which it occurs. Prevalence is defined as the number of cases of a condition, e.g., hypoxemia, present in a specified population at a given time.) Also, we sought to determine whether various patient factors are associated with an increased risk of postoperative hypoxemia.

METHODS

After approval was obtained from the Institutional Review Board, all patients who passed through the recovery areas at Brigham and Women's Hospital during a 5-

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day period were entered into the study. Routine recovery room care was not altered by the study protocol. Generally, oxygen is not routinely administered preoperatively or during transport from the operating room to the recovery area. Oxygen is usually administered for the first 10 minutes of the recovery room stay and then continued at the discretion of the recovery room clinician. Patients admitted directly to an intensive care unit from the operating room were excluded from the study.

A pulse oximeter (Ohmeda Biox Model 3700) was used to measure SaO_2 preoperatively, 5 minutes after arrival in the recovery room, 30 minutes later, and immediately before discharge. Patients were excluded from further data collection if the recovery room staff instituted pulse oximetry monitoring independent of the study.

The numeric display and audio output of the oximeter were disabled so the investigators, recovery room staff, and patient were unaware of the readings. The pulse waveform and amplitude indicator of the oximeter were observed to visually reject artifact. A computer collected data from the serial communications output of the oximeter, filtered them for artifact, and stored the filtered data for later analysis.

Filtering criteria for acceptance of data by the computer were: (1) the presence of a set of six consecutive readings, 3 seconds apart, in which the SaO_2 was between 40 and 100% and the pulse was between 40 and 160 beats per minute, and (2) each SaO_2 and pulse reading being within three units of the previous reading.

Gender, age, body habitus, American Society of Anesthesiologists (ASA) physical status, respiratory function, premedication, anesthetic technique and duration, surgical site, and intraoperative fluid administration were extracted from each patient's hospital record.

Body habitus was classified as obese if weight was greater than 120% of ideal [4]. Moderate respiratory dysfunction was recorded if the patient's physical status was classified as ASA I or II by respiratory evaluation but the patient had a history of asthma or smoking. Severe respiratory dysfunction was noted if the patient's physical status, based on respiratory evaluation, was ASA III or greater. Surgical site was classified as body cavity if the procedure was intrathoracic or intraabdominal; all other procedures were considered peripheral.

At the time of each SaO_2 measurement, level of consciousness was recorded as awake if the patient's eyes were open or asleep if they were closed. The patient was considered head-up if the head of the bed was at greater than 45 degrees. The administration of supplemental oxygen by nasal cannulae, face mask, or tracheal tube was also recorded.

The prevalence of hypoxemia at each measurement time was computed. The association of each potential risk factor to the proportion of hypoxemic patients was determined using Fisher's exact tests for two-category factors and Mann-Whitney U tests for ordered categorical data. The proportions of risk factors among inpatients and outpatients were compared using a chi-squared test. A P value of <0.05 was considered significant.

RESULTS

Of the 149 inpatients studied, one or more hypoxemic measurements were made in 21 (14%) during their postoperative care. The 92 ambulatory surgical patients had a significantly lower prevalence of hypoxemia; in 1 patient (1%), two SaO_2 measurements of 90% or less occurred, one at five minutes after arrival and one 30 minutes later.

The pulse oximeter was always successful in measuring SaO_2. We were able to obtain a total of 518 measurements from the inpatients: 144 preoperatively, 135 five minutes after arrival in recovery, 131 thirty minutes later, and 108 at discharge. The lowest SaO_2 recorded was 83%. Seven inpatients (5%) were excluded from further data collection because the recovery room team used pulse oximetry monitoring independent of the study.

For inpatients, the prevalence of hypoxemia preoperatively, 5 minutes after arrival in recovery, 30 minutes later, and at discharge was 2%, 4%, 6%, and 9%, respectively. Of these, only the preoperative versus discharge pair was significantly different. Postoperatively, the differences in frequency of hypoxemic readings when the patients' eyes were open (5%) versus closed (7%) and when the head of the bed was elevated (7%) versus flat (5%) were not significantly different. However, there was a significant difference in the frequency of hypoxemic readings taken with patients breathing room air (8%) versus supplemental oxygen (3%). The relationship of each factor to the prevalence of hypoxemia is shown in Table 1.

Inpatient factors associated with a significantly higher prevalence of hypoxemia were age over 40 years (18%), obesity (22%), ASA physical status (I, 7%; II, 17%; III, 18%; IV, 100%), duration of anesthesia longer than 90 minutes (18%), body cavity surgical procedures (24%), and administration of more than 1,500 ml of intraoperative fluid (20%). None of the other factors (gender, respiratory status, premedication, or anesthetic technique) were associated with hypoxemia. The prevalence and P values for each patient factor are listed in Table 2.

A comparison of the inpatient and outpatient groups

Table 1. Relationship of Measurement Factors to Prevalence of Hypoxemia in Inpatients

Factor	No. of Hypoxemic Episodes	Total No. of Events	No. of Hypoxemic/ Total Measurements (%)	*P* Value
Measurement time				0.06
Preoperative	3	144	2	
Postoperative	5	135	4	
Recovery room	8	131	6	
Discharge	10	108	9	
Level of consciousness				0.47
Eyes open	10	190	5	
Eyes closed	13	184	7	
Bed elevated				0.63
No	8	148	5	
Yes	15	226	7	
Supplemental oxygen				0.04
Yes	4	141	3	
No	19	233	8	

demonstrated major differences in these populations. Table 3 shows that, in outpatients, a higher proportion of measurements were made with eyes open and with bed elevated, and a lower proportion of measurements were made with supplemental oxygen. Table 4 shows that the outpatient group had a significantly greater proportion of the following: female subjects, age less than 40 years old, ASA physical status I and II, no premedication, general anesthesia, anesthesia lasting less than 90 minutes, body cavity surgical procedures, and intraoperative fluid administration less than 1,500 ml.

DISCUSSION

Clinical observation combined with the present standard of monitoring practice does not detect or prevent hypoxemia in all patients throughout their stay in the recovery room. In fact, we found the highest prevalence of hypoxemia at discharge, a time when the patient is carefully evaluated before transfer to an area of lower-level care.

Preoperatively, 3 patients were hypoxemic breathing room air. Two were maintained on supplemental oxygen postoperatively and had no subsequent hypoxemic readings. The third did not receive supplemental oxygen postoperatively and was hypoxemic at the 5- and 30-minute readings.

The charts of the 20 patients who became hypoxemic postoperatively were reviewed by an anesthesiologist (R.W.M.). In 5 of these patients, a plausible explanation could be constructed for the hypoxemia based on the preoperative data. One patient undergoing drainage of an empyema was given supplemental oxygen preoperatively but not postoperatively. Two were obese and had recognized lung disease. A 91-year-old, confused patient had a pleural effusion and chronic obstructive pulmonary disease (COPD). Another patient with COPD had an SaO_2 of 92% on preoperative blood gas analysis.

In 5 patients, explanations for desaturation were less clear: a recent upper respiratory infection, rheumatoid arthritis with asymptomatic airway involvement, inactive chronic bronchitis, early COPD diagnosed by chest roentgenogram in a 40-pack-year smoker, and a history of a 70% body surface burn four years earlier.

Two of the patients whose hemoglobin was found to have desaturated postoperatively were noted also to have desaturated hemoglobin intraoperatively. One regurgitated on induction of anesthesia, and the other appeared to have suffered a transient endobronchial intubation. In the remaining 8 patients, no specific causes for the hypoxemic readings were discovered.

It is important to note that continuous monitoring of SaO_2 could have demonstrated a much higher incidence of hypoxemia than we would presume from the 14% prevalence in inpatients and 1% prevalence in outpatients we observed by using intermittent measurements.

From our measurement of 1% prevalence, we conclude that outpatients have a relatively low incidence of postoperative hypoxemia (11/1,000; 95% confidence limits on the prevalence are 59/1,000 and 2/1,000). This finding may relate to differences in the presence or absence of some of the factors associated with hypoxemia in our inpatient group. Our data suggest that pulse oximetry be made available in the outpatient recovery area. The decision to monitor all outpatients in the postoperative period must be based on the particular circumstances of the outpatient unit, including the patient

Table 2. Relationship of Inpatient Factors to Prevalence of Hypoxemia

	Patients			
Factor	No. of Hypoxemic	Total No.	No. of Hypoxemic/ Total (%)	*P* Value
Sex				0.37
Female	11	91	12	
Male	10	58	17	
Age				0.03
≤40 yrs	2	43	5	
>40 yrs	19	106	18	
Body habitus				0.03
Normal	9	95	9	
Obese	12	54	22	
ASA physical status				0.03
I	4	54	7	
II	11	66	17	
III	5	28	18	
IV	1	1	100	
Respiratory function				0.10
Normal	10	88	11	
Moderate dysfunction	10	60	17	
Severe dysfunction	1	1	100	
Premedication				0.13
None	5	59	8	
Sedative	6	25	24	
Narcotics ± sedative	10	65	15	
Anesthetic technique				0.32
Regional	6	57	11	
General	15	92	16	
Duration of anesthesia				0.04
≤90 min	3	50	6	
>90 min	18	99	18	
Surgical site				0.04
Peripheral	12	112	11	
Body cavity	9	37	24	
Intraoperative fluid administration				0.03
≤1,500 ml	5	69	7	
>1,500 ml	16	80	20	

ASA = American Society of Anesthesiologists.

Table 3. Proportions of Measurement Factors among Inpatients and Outpatients

Factor	Inpatients (%)	Outpatients (%)
Level of consciousness[a]		
Eyes open	51	71
Eyes closed	49	29
Bed elevated[a]		
No	40	17
Yes	60	83
Supplemental oxygen[a]		
Yes	38	25
No	62	75

[a] $P < 0.05$

population, types of surgical procedures, and practices of the anesthesiologists.

Inpatients are at significant risk of becoming hypoxemic (141/1,000; 95% confidence limits are 200/1,000 and 94/1,000). The association of hypoxemia with ASA physical status, age greater than 40 years, obesity, lengthy surgical procedures, body cavity surgical procedures, large intraoperative fluid administration, and breathing of room air postoperatively is consistent with traditional teaching. However, it is important to recognize that hypoxemia also occurs frequently in inpatients lacking these risk factors.

Unrecognized hypoxemia in postsurgical inpatients with or without these risk factors is common. There-

Table 4. Proportions of Risk Factors among Inpatients and Outpatients

Factor	Inpatients (%)	Outpatients (%)
Sex[a]		
Female	61	88
Male	39	12
Age[a]		
≤40 yrs	28	72
>40 yrs	72	28
Body habitus		
Normal	64	70
Obese	36	30
ASA physical status[a]		
I	36	65
II	44	31
III–IV	20	4
Respiratory function		
Normal	59	70
Moderate dysfunction	40	30
Severe dysfunction	1	0
Premedication[a]		
None	39	99
Sedative	17	0
Narcotics ± sedative	44	1
Anesthetic technique[a]		
Regional	38	21
General	62	79
Duration of anesthesia[a]		
≤90 min	34	90
>90 min	66	10
Surgical site[a]		
Peripheral	75	46
Body cavity	25	54
Intraoperative fluid administration[a]		
≤1,500 ml	54	97
>1,500 ml	46	3

[a] $P < 0.05$

ASA = American Society of Anesthesiologists.

fore, routine monitoring of these patients with a pulse oximeter is suggested.

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