Postoperative Recovery of Arterial Oxygen Saturation Determined by Pulse Oximetry in Pediatric Patients

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Small children are physiologically subject to arterial oxygen desaturation. However, few reports have referred to the risk factors related to postanesthetic hypoxemia and the duration of hypoxemia. The purpose of this study was to clarify these two aspects. Eighty-five ASA physical status I infants and children were included in the study. They were scheduled for minor surgery. Fifty-six underwent oral endotracheal intubation, and 29 patients breathed from a mask. Anesthesia was maintained with Enflurane or Halothane and nitrous oxide.

Arterial oxygen saturation was measured with a pulse oximeter. The measurements were started shortly after patients' arrival in the recovery room, and conducted every 5 min at least for 1 hour. Ten patients had Sp_{O_2} values of less than 95%. In all except one, Sp_{O_2} decreased within 10 min after arrival in the recovery room. Age, height, and weight of these 10 children were significantly different from the remaining 75, but there were no significant differences in anesthetic duration and postanesthetic awakefulness between the group with postanesthetic hypoxemia and the one without. The importance of monitoring the clinical condition of pediatric patients after general anesthesia is universally acknowledged. Monitoring with the pulse oximeter has proven very useful and shows that, unless oxygen saturation is monitored, all children should receive supplemental oxygen. (Key words: pediatric anesthesia, postanesthetic, hypoxemia, pulse oximetry, oxygen saturation)

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In adult patients, general anesthesia disturbs pulmonary gas exchange and increases the alveolar-arterial oxygen tension gradient[1–5]. In pediatric patients, the incidence of hypoxemia after general anesthesia is still a matter of conjecture because until now no noninvasive technique to monitor arterial oxygenation has been available. The development of the pulse oximeter, however, has now made noninvasive evaluation possible. A few authors have already published reports on the incidence of hypoxemia in pe-

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diatric patients[6,7]. However, hardly any reports have referred to the risk factors related to postanesthetic hypoxemia and the duration of postanesthetic hemoglobin desaturation in children. The purpose of this study was to investigate and clarify these two aspects.

Methods

After approval by the ethical committee of our institution was obtained, 85 ASA physical status I infants and children (mean age: 3.3 years; range: 2 months to 9 years) were included in the study. They were scheduled for minor elective surgical procedures, such as inguinal herniorrhaphy, orchidopexy, and removal of cervical cyst under general anesthesia. The parents of all the patients were fully informed about the study. To minimize the effect of factors producing postanesthetic hemoglobin desaturation, only patients anesthetized with inhalational agents (halothane or enflurane) were selected.

Twenty-one patients received a rectal H_2 blocker, famotidine (1 $mg{\cdot}kg^{-1}$), as premedication. The remaining cases received the same dose of famotidine and diazepam (0.5 $mg{\cdot}kg^{-1}$). Induction was accomplished by inhalation of 2–4% enflurane or 1–3% halothane and 67% nitrous oxide in oxygen. Fifty-six patients underwent oral endotracheal intubation with 0.15 $mg{\cdot}kg^{-1}$ of vecuronium, while 29 breathed from a mask without any muscle relaxants. Anesthesia was maintained with the same agents accompanied by assisted or controlled ventilation. Patients given vecuronium received intravenous doses of atropine (0.03 $mg{\cdot}kg^{-1}$) and neostigmine (0.09 $mg{\cdot}kg^{-1}$) for reversal. They were given 100% oxygen by mask for at least 3 min after extubation. The remaining patients breathed 100% oxygen for at least 3 min after the nitrous oxide had been turned off and adequate spontaneous breathing had been established. Transport from the operating room to the recovery room took 3–5 min, during which time the patients did not receive any oxygen.

Arterial oxygen saturation (Sp_{O_2}) was measured with a pulse oximeter (Nellcor, Inc., Hayward CA) with its sensor attached to a finger or toe. Preoperative measurements were performed in the waiting area of the hospital 15 min after arrival on the morning of the operation. Postoperative measurements were started shortly after arrival in the recovery room (RR), and conducted every 5 min at least for 1 hour. In the cases of hypoxemia, Sp_{O_2} measurements were continued every 5 min until the digital display on the oximeter constantly indicated more than 95%. All patients were breathing room air spontaneously. The digital reading of Sp_{O_2} together with an accurate pulsation was recorded. Sp_{O_2} of less than 95% was chosen as the upper limit of hypoxemia. Duration of $Sp_{O_2} < 95\%$ was also recorded. If Sp_{O_2} decreased to less than 90%, supplemental oxygen was given by mask. This supplemental oxygen supply was interrupted every 5 min under careful observation. Sp_{O_2} was monitored until the patients achieved an Sp_{O_2} of at least 95% while breathing room air. The postanesthetic recovery (PAR) score was established with the modified Aldrich's scoring system[8].

The patients were divided into two groups on the basis of whether they did (H group) or did not (N group) have an episode of postanesthetic hypoxemia. Age, height, weight, and duration of anesthesia time were recorded for both groups. Analysis of variance of repeated measures was performed with the appropriate t-test. The correlation between PAR score, symptoms of the common cold, anesthetic technique, and anesthetic agents on the

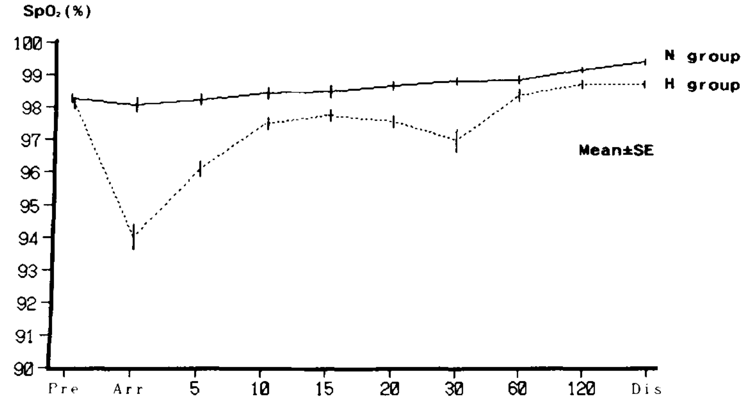

Fig. 1. Time course of Sp_{O_2} for each group. On arrival of the patients in the recovery room and 5 min later, the Sp_{O_2} for the two grups was significantly different. Thirty min after arrival, it was also significantly different, but this was due to one patient who developed severe hypoxemia at this point. Sp_{O_2} for the H group on arrival in the RR and 5 min later was also significantly different from preoperative values.

Pre, Preoperative period; Arr, On arrival in the recovery room; Dis, Discharge

Table 1. Clinical profiles and risk factors for the two groups

	H group	N group	
Age (month)	17.8 ± 16.12	43.2 ± 29.11	$P < 0.01$
Height (cm)	74.8 ± 13.28	94.9 ± 19.78	$P < 0.01$
Weight (kg)	9.2 ± 3.05	14.3 ± 5.53	$P < 0.01$
A. Time (min)	70.1 ± 25.53	64.4 ± 39.44	NS
PAR score>6/<6	1/9	3/72	NS
Common Cold+/−	2/8	8/67	NS
Famo./Dia.+Famo.	1/9	20/55	NS
Enflurane/Halothane	8/2	48/27	NS

Abbreviations. A. Time, Anesthetic Time; H group, patients with an episode of postanesthetic hypoxemia; N group, patients without an episode of postanesthetic hypoxemia; Famo., patients who received famotidine as premedication; Dia.+Famo., patients who received diazepam and famotidine as premedication.

one hand and the incidence of hypoxemia on the other was evaluated with the chi-square test. A P value of < 0.05 was considered statistically significant.

Results

On arrival in the RR, none of the patients showed any airway obstruction and their ventilatory condition was clinically adequate. Ten of the 85 patients showed Sp_{O_2} values of less than 95%. In all except one, Sp_{O_2} decreased within 10 min after arrival in the RR. This decrease was transient and returned spontaneously to more than 95% without any therapy. The duration of hypoxemia ranged from 30 to 260 sec (mean: 77.6 sec.). One patient, a 4-month-old boy, had Sp_{O_2} of less than 90%. His Sp_{O_2} value was over 95% on arrival in the RR, but it decreased to less than 95% 24 min after arrival and 3 min later to less than 90%. Supplemental oxygen by mask increased Sp_{O_2} immediately. Hypoxemia, or Sp_{O_2} of less than 90%, continued for about 30 min. After that, no episode of hypoxemia was detected during his 4-hour hospital stay.

Figure 1 shows the time course of Sp_{O_2} for the H and N groups. Sp_{O_2} on arrival in the RR and at 5 min after arrival was significantly lower for the H group than the N group and than preoperative values of the H group patients themselves. Sp_{O_2} at 10 min was similar for both groups. At 30 min, however, Sp_{O_2} was significantly different due to hypoxemia of one patient as described above.

Age, height, weight, and duration of anesthesia for both groups are shown in Table 1. Age, height, and weight were significantly different ($P < 0.01$), but there was no such significant difference in anesthetic duration between the two groups. PAR scores and the presence of common cold symptoms for both groups are shown in table 1, too. No significant relation was detected between incidence of hypoxemia and either PAR score or symptoms of the common cold. Type of inhalational agent, premedication, and anesthetic technique (intubation or mask ventilation) showed no correlation with hypoxemia, either.

Discussion

General anesthesia reduces functional residual capacity and deteriorates pulmonary gas exchange[1–4]. In adult patients, these dysfunctions continue into the postoperative period, while the residual effect of anesthetic agents on the respiratory center reduces its response to hypoxemia. Small children, furthermore, are physiologically subject to arterial oxygen desaturation, and some authors have suggested that the incidence of postanesthetic hypoxemia is surprisingly high[6,7,9]. However, few reports have referred to risk factors which induce postoperative hypoxemia, the most vulnerable time, and the duration.

The incidence of hypoxemia in the present study was lower than that described in other reports[6–8,9]. The high PAR score of our patients may be one reason. Soliman et al.[7] reported that the PAR score did not correlate with the incidence of hypoxemia measured by pulse oximeter. In his study, 57 of 81 patients had a PAR score of 6 or less, while only 4 of 85 patients in the present study had a similarly low PAR score. If the difference in PAR score between two studies relates to the difference in hypoxemia incidence, the degree of wakefulness may be an important factor.

The duration of hypoxemic episodes has never been reported in detail. Motoyama reported that Sp_{O_2} at 5–15 min after the initial measurement was still significantly lower than preoperative values. However, he did not determine the duration of hypoxemia. In the present study, Sp_{O_2} for the H and N groups at 10 min showed no significant difference. Inhalational agents may have an adverse effect on pulmonary hypoxic vasoconstriction and increase the alveolar-arterial oxygen tension gradient[10]. The residual effect of these agents probably plays an important role in postanesthetic hypoxemia. However, the PAR score of our patients was so high that the residual effect of the agents might be less than in other studies. This may be the reason why the duration of hypoxemia for our patients was short and transient.

Age, height, and weight of the H

group were significantly less than for the N group. Nine of the 10 patients in the H group were less than two years old. Kataria et al.[11] measured Sp_{O_2} of pediatric patients during transportation after operation. In their study, desaturation was most notable in the 0–6 month age group, followed by the 7–12 month age group. Such small children are subject to postanesthetic hypoxemia due to physiological features, such as increased susceptibility to airway closure and the severe reduction in FRC during anesthesia due to low elastic recoil of the thorax and lungs[12–14].

In conclusion, the incidence of hypoxemia was high in small children, especially those less than two years old. It occurred within 10 min after arrival in the RR and the duration was less than 5 min, but this did not depend on the degree of wakefulness. It is, therefore, important to the clinical condition of pediatric patients, especially those younger than two years, during the early postanesthetic period. Monitoring with the pulse oximeter has proven very useful and shows that, unless oxygen saturation is monitored, all children should receive supplemental oxygen.

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