Ambulatory Surgery 6 (1998) 93–96

The optimum flow of blow-by oxygen for paediatric patients in a post-anaesthesic care unit

S. Suraseranivongse [a,*], S. Maneenoy [b], C. Komoltri [b], S. Foongdej [c]

[a] *Department of Anaesthesiology, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Prannok Road, Bangkok 10700, Thailand.*
[b] *Computer center, Siriraj Hospital, Mahidol University, 2 Prannok Road, Bangkok 10700, Thailand*
[c] *Department of Nursing, Siriraj Hospital, Mahidol University, 2 Prannok Road, Bangkok 10700, Thailand*

Received 10 November 1997; accepted 12 November 1997

Abstract

A randomized cross-over study aimed to compare the efficacy of various flows of blow-by oxygen supplement in paediatric patients recovering from anaesthesia. A total of 24 infants and children of the American Society of Anesthesiologists (ASA) class I, age 10 months to 7 years, were studied. After lower abdominal or peripheral surgery on an ambulatory basis in the post-anaesthesia care unit, three flows of oxygen (3, 4 and 5 l/min) were delivered in randomized sequence, 10 min for each flow. Haemoglobin oxygen saturation (S_pO_2) was recorded before receiving oxygen (control group) and 10 min after changing the flows. The results showed that the S_pO_2 of all oxygenated groups (flow 3, 4 and 5 l/min: S_pO_2 98.7, 99.0 and 99.2%, respectively) was significantly higher than the control (95.7%). The lowest S_pO_2 obtained from the oxygenated groups of 3, 4 and 5 l/min was 95, 96 and 97%, respectively. We concluded that an oxygen flow of 3 l/min was the optimum flow to prevent post-operative hypoxaemia in paediatric patients.

Keywords: Blow-by oxygen; PACU; Paediatric; Optimum flow

1. Introduction

Hypoxaemia is commonly found in infants and children following general anaesthesia [1,2]. In a study of post-operative arterial desaturation in paediatric patients monitored by oximeter (S_pO_2), hypoxaemia ($S_pO_2 < 91\%$) occurred in 28% of patients who inspired room air during transfer to the recovery room [3]. Motoyama et al. (1986) detected significant arterial desaturation ($S_pO_2 \leq 90\%$) for 15 min [4]. Therefore, an oxygen supplement for infants and children following general anaesthesia is recommended. Amar et al. (1991) [5] introduced blow-by oxygen technique, using a corrugated tube connected to a nebulizer with the other end of corrugated tube placed 4–5 cm from the patient's mouth and nose. They compared the effect of an oxygen supplement via blow-by and face mask in paediatric patients with low risk and high risk of post-operative hypoxaemia. S_pO_2 in the blow-by group was significantly higher than in the face mask group because blow-by was better tolerated than the face mask. Fresh gas flows for blow-by in that study were 6–8 l/min for patients under 2 years and 8–10 l/min for patients aged over 2 years. Our study investigated the effect of lower fresh gas flow of 3, 4 and 5 l/min on prevention of post-operative hypoxaemia to find the optimum flow which was also the lowest flow that could provide sufficient oxygenation.

2. Methods

A prospective randomized cross-over study was carried out in 39 outpatients, ASA class I and II. They underwent lower abdominal or peripheral surgery without any limitation of anaesthetic techniques or drugs.

* Corresponding author. Fax: +66 2 4121371.

0966-6532/98/$19.00
PII S0966-6532(97)10019-1

Table 1
S_pO_2 measurement in the recovery room ($n = 24$)

	Group 1 (control)	Group 2 (3 l/min)	Group 3 (4 l/min)	Group 4 (5 l/min)
S_pO_2 (mean ± S.D.)	95.7 ± 2.3	98.7 ± 1.4*+	99.0 ± 2.2*	99.2 ± 2.0*+
S_pO_2 (range)	90–98	95–100	96–100	97–100

* Significant difference from control (group 1).
+ Significant difference between groups 2 and 4.

Exclusion criteria were: a history of cardiac or pulmonary disease, infection within 2 weeks and axillary temperature below 35.5°C. All patients were transferred from the operating theatre to the post-anaesthesia care unit (PACU) without an oxygen supplement. The oxygen was delivered to all patients by an O_2 nebulizer via the blow-by technique. All patients received three different fresh gas flows of 3, 4 and 5 l/min. The sequence of flows was randomized to prevent bias from the hypoventilating effect of residual anaesthetics or awakening. Each flow was delivered for 10 min, e.g. patient no. 1 received an O_2 flow of 3, 4 and 5 l/min, patient no. 2 received O_2 flow 5, 3 and 4 l/min, patient no. 3 received O_2 flow 3, 5 and 4 l/min etc.

S_pO_2 was continuously monitored for 30 min by Ohmeda 3700 Biox pulse oximeter. S_pO_2 was recorded before oxygen supplementation as control S_pO_2 and every 10 min after each change of flow rate. If S_pO_2 was 91% or lower at any time of continuous monitoring, hypoxaemia would be recorded and O_2 flow would be increased. If the patients woke up and refused oxygen before receiving all three flows, only S_pO_2 of the used flows were recorded.

All S_pO_2 data were analyzed by allocation into four groups: group 1, S_pO_2 of control group without O_2; group 2, S_pO_2 of O_2 flow 3 l/min; group 3, S_pO_2 of O_2 flow 4 l/min; and group 4, S_pO_2 of O_2 flow 5 l/min S_pO_2 were compared by using Friedman analysis. A P-value of less than 0.05 was considered to be statistically significant.

3. Results

A total of 39 patients aged 5 months to 7 years, weighed 4–25 kg. ASA class I were included in this study: 39 patients in group 1; 32 patients in group 2; 35 patients in group 3; and 32 patients in group 4. The total number of patients in each group was not equal because some patients woke up and refused O_2 before completing all three flows. By using Friedman analysis, only 24 patients with complete data of three flows were included. (age 10 months to 7 years, weighed 8.5–25 kg). There were no patients who had S_pO_2 lower than 97% in the excluded group.

S_pO_2 measurement in the four groups is illustrated in Table 1 and Fig. 1. Groups 2, 3 and 4 were significantly higher than group 1 ($P < 0.0001$) and group 4 was significantly higher than group 2 ($P < 0.0001$). Even though the actual sample size was less than predicted, further data was not necessary because of high statistical significance.

Blow-by oxygen was well tolerated by all patients until waking up. In control group arterial oxygen desaturation ($S_pO_2 \leq 90\%$) was found in one patient (4.2%). In oxygenated groups (groups 2, 3 and 4), no arterial oxygen desaturation ($S_pO_2 < 90\%$) was found. The lowest S_pO_2 of groups 2, 3 and 4 were 95, 96 and 97%, respectively.

4. Discussion

Hypoxaemia commonly occurred following general anaesthesia in adults and children [3,4,6]due to several causes, e.g. residual anaesthetics action on respiratory centers and altered ventilatory response to hypoxia and hypercarbia [7], inadequate neuromuscular activity, airway obstruction [2] or secretion obstruction, post-operative hypoventilation due to intraoperative hyperventilation and alkalosis. Hypothermia and shivering also increase oxygen consumption and decrease mixed venous oxygen tension. Infants and children had higher risk of post-anaesthetic arterial desaturation due

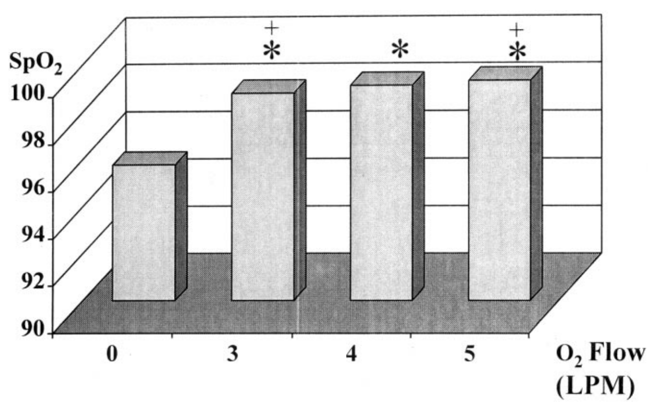

Fig. 1. S_pO_2 in recovery room. * Significant difference from control group (no O_2). + Significant difference between O_2 3 and O_2 5 l/min groups.

to higher basal metabolic rate, higher ratio of alveolar ventilation to functional residual capacity (FRC) and higher closing capacity [8].

The incidence of post-operative hypoxaemia was reported in several studies. Vijayakumar [9] found hypoxaemia ($S_pO_2 \leq 90\%$) in 26% of paediatric patients on arrival in the recovery room. Pullerits [3] detected severe arterial oxygen desaturation ($S_pO_2 \leq 85\%$) in 12.7% of children during transfer to the recovery room. Canet [10] reported hypoxaemia ($S_pO_2 \leq 90\%$) in 43% of paediatric patients, 10 min after arrival in the recovery room and severe hypoxaemia ($S_pO_2 \leq 85\%$) in 11.4% of the patients. Motoyama and Glazener [4] measured S_pO_2 in 97 children and found that the S_pO_2 on arrival in PACU was 93% and increased to 94.1%, 5–10 min later. Canet et al. [10] monitored S_pO_2 in 209 children who inspired room air. S_pO_2 in the first 10 min on arrival in PACU was 90.7%, 10 min later S_pO_2. was 92.4% and 1 h later was 93.2%. S_pO_2 increased as time passed because the effects of residual anaesthetics gradually decreased. The most critical period of post-operative hypoxaemia was the first 20 min. The incidence of post-operative hypoxaemia in our study was only 4.2%.

Amar [5] compared the efficacy of blow-by and face mask techniques delivering oxygen to 66 children in PACU. All patients in the blow-by group tolerated this method very well whereas 20% of patients in the face mask group were agitated and refused the mask (which might also cause injury to the eye). Using fresh gas flow of 6–8 l/min in patients aged under 2 years and flow 8–10 l/min in patients over 2 years, S_pO_2 increased 99–100% which was significantly higher than baseline in both low risk healthy children and high risk (heart disease, respiratory disease, haematologic disease, obesity, pre-maturity (post-conceptual age < 50 week). Blow-by oxygen might cause apnea and bradycardia from diving reflex in new-borns. Amar did not recommend blow-by in severe hypoxaemia from laryngospasm in which a closed system with a reservoir gave a better result.

This study revealed that the blow-by technique was well tolerated in paediatric patients. Lower fresh gas flows than the previous study [5] could increase S_pO_2 from 95.7% (control) to an acceptable level (98.7, 99.1 and 99.2% from flow 3, 4 and 5 l/min, respectively). F_iO_2 from each flow in the smallest patient (8 kg) and the biggest patient (25 kg) were calculated by using Shapiro's guideline [11]. The average oxygen concentration measured close to the nose of five patients by oximeter was 0.91, 0.97 and 100% from oxygen flow 3, 4 and 5 l/min, respectively.

Example. A child weighed 8 kg, RR 40/min (from Stafford: normal values of respiratory rates in children [12]), tidal volume 7 ml/kg (56 ml). Fresh gas flow, 3 l/min; I:E, 1:2; respiratory cycle, 1.5 s; total inspired gas (T_i), 0.5 s; and required inspired gas, 56 ml. T_i in 0.5 s is derived from:

(1) FGF $(3000/60)\times 0.5$	$= 25$ ml of O_2 91%
(2) Air entrained	$= 31$ ml of O_2 20%
$\therefore F_iO_2 = (22.75+6.2)/56$	$= 0.52$
Fresh gas flow 4 l/min	$F_iO_2 = 0.84$
Fresh gas flow 5 l/min	$F_iO_2 = 1.0$

A child weighed 25 kg, RR 25/min (from Stafford: normal values for respiratory in children [12]) tidal volume 7 ml/kg (= 175 ml)

Fresh gas flow 3 l/min;
$F_iO_2 = 0.36$
Fresh gas flow 4 l/min;
$F_iO_2 = 0.43$
Fresh gas flow 5 l/min;
$F_iO_2 = 0.51$

Corresponding to the studies of Conway and Payne [13] and Canet [10], $F_iO_2 = 0.35$ was sufficient to prevent post-operative hypoxaemia. The lowest predicted F_iO_2 from O_2 flow 3 l/min was 0.36 which should be adequate and we found no arterial desaturation ($S_pO_2 \leq 90\%$) in the oxygenated group. The lowest S_pO_2 of the oxygenated group was 95% from group 2 (3 l/min). By similar calculation, the lowest predicted F_iO_2 from O_2 flow 2 l/min was 0.32 which might not be sufficient, therefore O_2 flow 3 l/min should be the optimum.

5. Conclusion

Blow-by oxygen delivery was well tolerated in post-operative paediatric patients in PACU. The optimum oxygen flow was 3 l/min.

Acknowledgements

The authors thank Associate Professor Jariya Lertakayamanee for research design and Professor Thara Trirakarn for kind suggestions.

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