EFFECTS OF LOW FLOW RATES ON THE INSPIRED OXYGEN CONCENTRATION IN CIRCLE ABSORBER CIRCUIT

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SYNOPSIS

Fresh gas flows into a circle circuit with carbon dioxide absorber were reduced from 6L to 0.75L/min and the effects on inspired oxygen concentration studied. A fall in inspired oxygen concentration below 30% was seen with flow rates less than 3 L/min.

INTRODUCTION

Low fresh gas flows of nitrous oxide and oxygen in a circle circuit with carbon dioxide absorber may be unsafe as it may result in a hypoxic mixture to the patient. The concentration of the gases within the circle circuit are effected by the rebreathing of expired alveolar gas. The expired alveolar gas would contain a lower concentration of oxygen and a higher concentration of carbon dioxide. However, the carbon dioxide is removed by carbon dioxide absorber. The oxygen concentration in the circle circuit will therefore fall, depending on the amount of rebreathing which will depend on the fresh gas flow-rate. The authors studied the effect of a gradual reduction in the fresh gas flow and observed a fall in the inspired oxygen concentration together with a concommitant fall in arterial oxygenation but little change in arterial PCO_2 levels.

The apparatus used consisted of a Standard Boyle Mark III circle circuit with a 4 lb. soda lime absorber (Durasorb). Manual ventilation was applied to a 2 litre reservoir bag, at a rate of 15 — 20 breaths per minute, with the overflow valve sited at the junction of the reservoir bag and the connecting corrugated tube to the circle circuit. Bulb samples were led from the inspiratory limb of the circle circuit through a column of silica gel to a Beckman D2 paramagnetic oxygen analyzer. (See Fig. 1). Calibration was performed with 100% nitrous oxide, 100% oxygen and room air before each set of readings. Readings were made to the nearest 5 mm $Hg0_2$ partial pressure. The delivered oxygen concentration was sampled at the fresh gas flow inlet.

The series consisted of 25 adult patients weighing 40 to 68 kg undergoing general surgical procedures (See Table 1).

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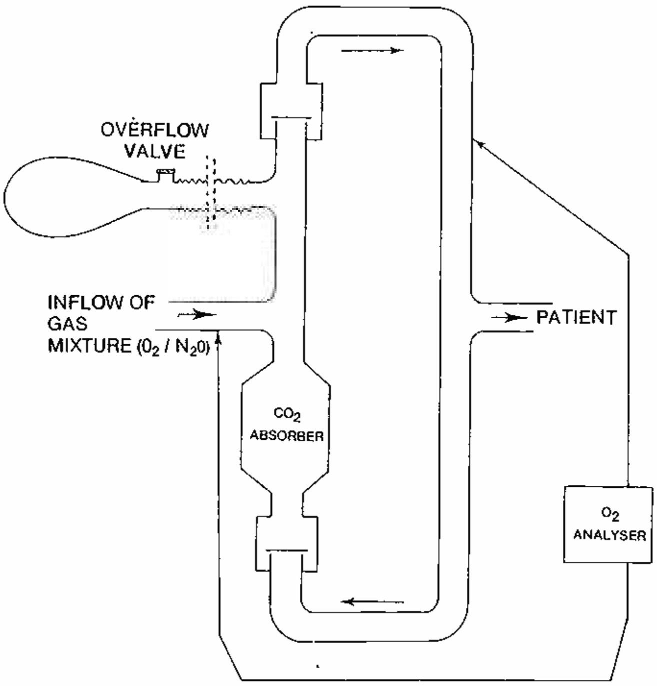


Fig. 1 Circuit for IPPV (manual) in study.

Number of patients	25
Age (years)	41 mean (22-63)
Weight (kg)	51 mean (40-68)
Pre-anaesthetic blood gases	
PaO_2 (mmHg)	84.4 mean (77-96) SD ± 7.32
$PaCO_2$ (mmHg)	45 mean (40-52) SD ± 4.39

TABLE 1

A SUMMARY OF THE DETAILS OF 25 PATIENTS WHO WERE STUDIED

Premedication consisting of morphine 0.2 mg/kg and atropine 0.6 mg intramuscularly was administered 1 hour before the procedure. A femoral arterial puncture was done to obtain the pre-anaesthetic blood gas picture. Induction was effected by intravenous thiopentone (4 mg/kg) followed by Suxamethonium and inhalation of a mixture of nitrous oxide (4 litres/min) and oxygen (2 litres/min). The patient was intubated and paralysed with either alcuronium (0.3 mg/kg) or tubocurare (0.5 mg/kg) and ventilated manually with oxygen 2 litres/min and nitrous oxide 4 litres/min using the circuit described. The radial artery was cannulated with a Scalp vein needle FG 21 and kept patent with a heparinised saline (0.9%) solution.

After 30 mins., a steady state is assumed and arterial blood is sampled after 3 constant readings of the inspired oxygen concentration at 2 min. intervals were made. Flow rates of oxygen and nitrous oxide were reduced in turn to each of the following: 1.5/3; 1/2; 0.75/1.5, 0.5/1.0, 0.25/0.5, in litres/min. For each flow rate, the flow was maintained for 30 minutes before the fresh gas concentration was checked and the inspired oxygen concentration taken at 2 min. intervals until 3 constant values were obtained. Radial arterial blood samples were taken when this was attained.

To check the validity of the steady state, readings were continued in 2 patients at flow rates 6 litres/min and 1.5 litres/min. for 60 minutes and 120 minutes, observing no change in the measured inspired oxygen concentration. After two complete series of readings, the order of flow was reversed to rule out bias caused by the possible effect of the previous gas mixture on the subsequent reading.

RESULTS

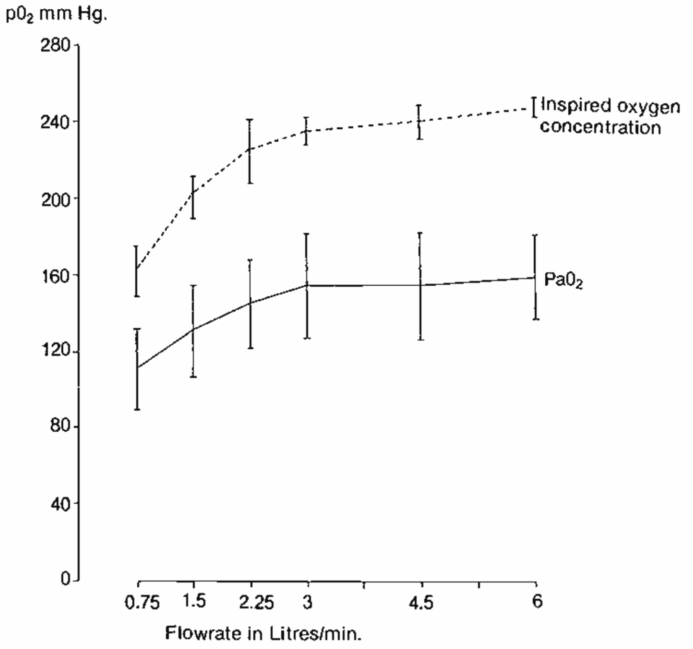
The results are shown in Table 2. The $PaCO_2$ levels were relatively constant with a range of 18.7 — 32 mmHg. This shows the relative efficiency of the soda-lime absorber.

The PaO_2 and the inspired oxygen concentration were closely related over the range of flow rates used. However, when the flow rates were below 3 Litres/min., the inspired oxygen concentration fell below 30% (see Fig. 2).

DISCUSSION

When low fresh gas flows of nitrous oxide and oxygen in a circle circuit with carbon dioxide absorber on manual ventilation are used, a reduction in the inspired oxygen concentration would result. In this clinical investigation, it was shown that the inspired oxygen concentration fell below 30% with flow rates below 3 L/min despite of

Fig. 2 The Relationship between Inspired Oxygen Concentration, paO_2 and Flowrate in Patients ventilated with Circle Circuit with carbon dioxide absorber (Soda-lime).



	FLOW RATES L/MIN					
	6	4.5	3.0	2.25	1.5	0.75
O_2/N_2O L/min	2/4	1.5/3.0	1.0/2.0	0.75/1.5	0.5/1.0	0.25/0.5
PaO_2 Mean mmHg	160	155.2	155.14	144.71	131.86	111.43
Range mmHg	126 — 192	100 — 189	110 — 189	115 — 183	102 — 162	82 — 135
S.D.	20.9	28.4	26.5	22.95	23.67	21.49
S.E.	7.91	10.76	10.04	8.67	8.95	8.12
Inspired Oxygen Concentration						
Mean Percent Conc. %	32.7	31.7	31.1	29.7	27.7	21.3
Mean O_2 tension mmHg	248.57	240.7	236.4	225.71	201.4	162.14
Range mmHg	240-225	225-250	225-245	200-240	185-215	145-180
S.D.	4.76	7.87	6.89	15.6	11.4	13.1
S.E.	1.8	2.97	2.6	5.92	4.32	4.98
PaCO_2 Mean mmHg	26.5	25.42	23.58	21.53	23.33	24.03
Range	20-29.5	21-29.5	20-29	18.7-25.5	20.5-24	19-32
S.D.	3.54	3.83	3.14	2.34	1.54	4.24
S.E.	1.45	1.56	1.28	0.96	0.63	1.73

TABLE 2

AN ANALYSIS OF THE BLOOD GAS VALUES OBTAINED WITH MANUAL VENTILATION USING THE CIRCLE SYSTEM AND THE EFFECTS OF REDUCED FRESH GAS FLOWS.

having a delivery oxygen concentration of 33%. This is due to the amount of expired alveolar gas entering the circuit, which contains a much reduced oxygen content. The lower the flow rate, the greater is the amount of expired alveolar gas entering the circuit, thereby lowering the inspired oxygen concentration. The carbon dioxide is very efficiently absorbed by the soda-lime absorber by the relatively constant $PaCO_2$ levels despite reduced flow rates. However, hypocarbia is not desirable (Pollard & Gibb, 1977).

However, low flows of gases may be advantageous in 2 respects:—

(a) economy of the gases used;

(b) a reduction of theatre pollution.

This is limited by the reduction of the inspired oxygen concentration which could be hazardous to the patient.

Caution is advised in the use of low flow rates in circle circuits if there is evidence of increased oxygen consumption such as hyperpyrexia, hyperthyroidism or muscle activity due to inadequate muscle relaxation as it may be inadequate in such states. The lack of accuracy of rotameters for low flow rates discourages the use of low flow rates. Should low flows be used, careful monitoring of the inspired oxygen should be made or perhaps a higher setting of oxygen flow would be required to ensure an inspired oxygen concentration of 30%.

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REFERENCES

1. Crowley, J.H., Faulconer, A., and Lundy, J.S. : Certain Factors Influencing the percentage of oxygen in mixtures of nitrous oxide and oxygen. Anaesth. Analgesia 27 : 255, 1948.
2. Forbes, A. R. : Inspired oxygen concentrations in Semi-closed Circle absorber Circuits with low flows of nitrous oxide and oxygen. Br. J. Anaesthesia, 44 : 1081, 1972.
3. Nunn, J. F. : Predictors for oxygen and carbon dioxide levels during anaesthesia. Anaesthesia, 17 : 182, 1962.
4. Nunn, J. F. : Applied Respiratory Physiology, 2nd Edition. Butterworth & Co. (Publishers), London, 1976.
5. Pollard, B. and Gibb, D.B. : Some adverse physiological effects of hypocarbia and methods of maintaining normocarbia during controlled ventilation — A Review. Anaesthesia & Intensive Care 5 : 113, 1977.
6. Raymond, J. A. : Prediction of inspired oxygen concentration within a circle anaesthetic system. Br. J. Anaesthesia, 48 : 217, 1976.