POST-OPERATIVE HYPOXAEMIA AND OXYGEN THERAPY

BY

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During preliminary experiments carried out on post-operative patients to study the efficiency of the Oxygenaire disposable oxygen mask it was observed that the control blood samples were desaturated. It was planned, therefore, to investigate not only the efficiency of the mask but also the incidence and extent of the oxygen desaturation and the effect of oxygen administration.

Method

The studies were carried out during the immediate post-operative period on patients of both sexes over the age of 21 admitted for a variety of surgical procedures under general anaesthesia. The nature of the investigation was explained to each patient and consent obtained. The details are set out in Table I.

Anaesthesia was induced with 300–500 mg. of 5% solution of thiopentone given intravenously followed by suxamethonium 40 mg. if intubation was indicated. Thereafter anaesthesia was continued with halothane and oxygen administered through a Magill attachment or from a closed-circle system with the vaporizer in the circle. Most patients breathed spontaneously, but in those undergoing peroral endoscopy anaesthesia was maintained by the apnoeic diffusion technique described by Holmdahl (1953) and Barth (1954).

Under anaesthesia a "polythene" catheter was inserted percutaneously into the radial artery just proximal to the left wrist-joint. The method of insertion was based on that of Seldinger (1953) and Holmgren (1956) and described in detail elsewhere (Payne, 1962). After insertion the catheter was filled with heparin-saline (1 mg./ml.) and sealed. Patency was maintained by refilling with heparin-saline after the removal of each blood sample. The blood samples were collected anaerobically in 10-ml. syringes lubricated with silicone oil. Heparin 10 mg./ml. served the double purpose of preventing coagulation and filling the syringe dead space.

The blood samples were used to determine the percentage oxygen saturation and the carbon-dioxide tension. The first sample was taken between one and two hours after the end of the operation when the patient was conscious and breathing room air. For the

following 20 minutes oxygen was administered through a face-mask at a rate of 2 litres a minute; at the end of this period a second blood sample was withdrawn and the oxygen administration rate increased to 4 litres/minute. After a further 20 minutes a third sample was taken, the oxygen administration stopped, and the patient allowed to breathe room air. Twenty minutes later the last blood sample was withdrawn and the arterial catheter removed. Firm pressure over the site of the insertion for three minutes prevented bleeding.

The percentage oxygen saturation was determined in duplicate by a photoelectric method using the Brinkman haemoreflexor. The Dill dissociation curve (Dittmer, 1958) was used to determine the corresponding oxygen tensions.

Carbon-dioxide tensions were obtained by the interpolation method of Siggaard Andersen, Engel, Jørgensen, and Astrup (1960) using an E.I.L. pH meter and the micro-electrode apparatus described by Robinson and Pimblett (1962) for the measurement of pH. The nomogram used was that constructed by Siggaard Andersen and Engel (1960).

Oxygen was administered by means of disposable face-masks (Oxygenaire) made of polyvinyl chloride. These masks are so designed that the oxygen inflow enters the mask by passing through an inflatable cuff; an inflow of 2 l./min. is enough to inflate the cuff and hold the mask in position against the patient's face. If the oxygen supply fails, the cuff deflates and the mask falls away from the face.

In five subjects the oxygen concentration within the mask was determined for flow rates of 2 and 4 l./min. by means of a Brinkman paramagnetic oxygen analyser. Samples for analysis were obtained through a fine polythene catheter threaded through the substance of the mask so that its tip lay close to the subject's upper lip. The subjects were studied at rest in both the supine and sitting positions.

Results

All arterial blood samples taken between one and two hours after the end of operation while the patients were breathing room air were desaturated. The mean percentage oxygen saturation was 88.98 (S.D. 6.04), corresponding to oxygen tensions of 62.3 ± 11.1 mm. Hg. The lowest oxygen saturation (75%) occurred in a relatively healthy patient undergoing iliac endarterectomy, whereas a patient anaesthetized for more than four hours for insertion of an aortic bifurcation graft showed only moderate desaturation (92%). With a mean carbon-dioxide tension of 38.24 mm. Hg the values were reasonably close to the normal and showed no evidence of underventilation.

When breathing oxygen supplied at a rate of 2 l./min. from a face-mask the mean inspired oxygen concentra-

TABLE I.—Details of 12 Cases Studied

Case	Age	Sex	Physical Status	Procedure	Duration	Premedication
1	67	F	Bronchitis	Femoral herniorrhaphy	45 mins.	Atropine, 0.6 mg.
2	47	M	Atheroma	Femoro-popliteal by-pass graft	2 hours	Pethidine, 100 mg. Atropine, 0.6 mg.
3	66	M	"	Aortic bifurcation graft	4½ "	Atropine, 0.6 mg.
4	56	M	Hypertension	Direct laryngoscopy	15 mins.	Pentobarbitone, 200 mg. Atropine, 0.6 mg.
5	61	M	Fit	"	12 "	" 200 " 0.6 "
6	63	M	Atheroma	Iliac endarterectomy	1½ hours	Pethidine, 100 mg. Atropine, 0.6 mg.
7	65	M	"	Excision femoral aneurysm	2 "	Atropine, 0.6 mg.
8	58	M	"	Femoro-popliteal by-pass graft	2½ "	" 0.6 "
9	47	M	Fit	Inguinal herniorrhaphy	1 hour	" 0.6 "
10	47	M	"	Oesophagoscopy	20 mins.	Pethidine, 100 mg. Atropine, 0.6 mg.
11	36	M	"	Inguinal herniorrhaphy	1½ hours	Atropine, 0.6 mg.
12	36	F	"	Stripping of varicose veins	40 mins.	Pentobarbitone, 200 mg. Atropine, 0.6 mg.

tion in five subjects was 38.8% in the sitting position and 38.8% lying down. After breathing such concentrations for 20 minutes the arterial oxygen saturation in 12 patients rose from a mean of 88.98 to 94.30 (S.D. 4.88) (Table II).

TABLE II.—*Post-operative Arterial Oxygen Saturations and Carbon-dioxide Tensions Before, During, and After Oxygen Administration*

Case	Oxygen Saturation (%)				Pco ₂ Levels (mm. Hg)			
	Control	Oxygen Therapy		Control	Control	Oxygen Therapy		Control
		2 l./min.	4 l./min.			2 l./min.	4 l./min.	
1	88.0	92.5	94.0	87.0	32.0	31.5	33.5	37.0
2	90.5	96.5	93.5	91.5	43.2	48.0	46.5	43.3
3	92.0	99.5	98.7	92.5	32.7	37.0	29.9	22.7
4	92.8	95.0	96.0	89.8	32.0	33.0	34.8	29.5
5	92.0	97.5	99.0	88.5	33.2	35.2	36.2	29.1
6	75.0	84.0	83.0	76.0	44.0	47.0	49.0	42.5
7	86.0	97.0	98.0	87.5	39.2	46.8	43.8	46.0
8	79.5	87.2	87.2	82.5	40.0	43.5	38.8	41.2
9	93.0	96.0	98.0	94.5	39.1	42.1	42.6	41.5
10	91.0	90.5	96.5	92.5	47.0	40.5	42.0	37.0
11	94.0	100.0	100.0	87.5	38.0	44.0	41.2	39.2
12	94.0	96.0	98.0	94.5	38.5	30.5	33.0	40.2
Mean	88.98	94.31	95.16	88.69	38.24	39.92	39.27	37.43
S.D.	6.04	4.88	5.16	5.32	4.98	6.29	5.87	6.91
Difference between any columns		P < 0.025			P > 0.25			
Difference between control and oxygen therapy columns		P < 0.01			0.4 > P > 0.3			

Increasing the flow rate of oxygen into the mask to 4 l./min. raised the inspired oxygen concentration to 50.8 in the sitting position and 54.4 lying down, but the mean arterial oxygen saturation (95.16—S.D. 5.16) was not significantly increased further. Withdrawal of the face-mask, however, led to a fall in the mean saturation values (88.69—S.D. 5.32) to around the control level. The differences between the arterial oxygen saturations obtained when the patients were breathing room air and those determined during oxygen therapy were statistically significant, as is shown by the result of the analysis of variance with a probability value smaller than 0.01 (Table II).

The carbon-dioxide tension remained virtually unchanged during the administration of oxygen and was not altered by return to room air (Table II).

Discussion

The fact that oxygen desaturation was present in every patient studied regardless of the patient's physical state, the type of operative procedure, or the nature of the premedication suggests that it is a consequence of general anaesthesia; and as it has since been shown to occur with cyclopropane, chloroform, and ether as well as with halothane (unpublished data), it cannot be attributed to any particular agent. The extent of the desaturation varied over a fairly wide range and was not obviously related to either the type or the duration of the anaesthetic or to the nature of the surgery. It remains to be determined whether relaxants with controlled respiration will modify this response to anaesthesia.

The virtually normal carbon-dioxide tensions obtained throughout the study exclude underventilation as a cause of the desaturation. The improvement in oxygen saturation with only moderately enriched oxygen mixtures supports the contention of Nunn and Payne (1962) that the desaturation is due to a disturbance in

the normal ventilation/perfusion relationship rather than to a frank shunt, since such shunts would not show the same tendency to improve on oxygen breathed under the conditions described.

The significance of post-operative hypoxia and the indications for oxygen therapy have been discussed elsewhere (Nunn and Payne, 1962), but the method of oxygen administration deserves further comment.

When oxygen therapy is indicated in the post-operative period several methods are available. For infants some form of incubator is needed; in older children and uncooperative adults a tent may be required, but for most patients a face-mask, if well designed, provides the most satisfactory method.

In practice the safety of the Oxygenaire disposable mask was confirmed; failure of the oxygen supply caused the mask to fall away from the patient's face, thus avoiding respiratory obstruction and at the same time providing visible evidence of the oxygen failure. Its efficiency was also established; a flow rate of oxygen as low as 2 l./min. into the mask was sufficient to provide an inspired oxygen concentration of more than 35% and to relieve the oxygen desaturation; it was also sufficient to wash out carbon dioxide, since in no patient did the arterial carbon-dioxide tension rise above 49 mm. Hg. Further advantages were the readiness of the patient to tolerate the mask for long periods, the simplicity and convenience in handling, and the low cost.

Summary

Arterial oxygen saturations and carbon-dioxide tensions were measured during the immediate post-operative period in a group of 12 patients submitted to a variety of surgical procedures. The measurements were made before, during, and after exposure to high inspired-oxygen tensions.

Oxygen desaturation was observed in every patient studied. This was relieved by the inspiration of an oxygen-enriched mixture, but the desaturation developed again when the oxygen was withdrawn. It could not be attributed to any particular anaesthetic agent, nor was it possible to demonstrate a direct relationship between its extent and the nature and duration of the operation.

Arterial carbon-dioxide tensions remained within normal limits throughout the study; thus it could also be concluded that underventilation was not the cause of the observed oxygen desaturation.

For the administration of an oxygen-enriched mixture the Oxygenaire disposable masks were shown to be safe and efficient; an oxygen flow rate of 2 litres per minute supplied through the mask relieved the desaturation and did not cause carbon-dioxide retention.

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