CARBON DIOXIDE ELIMINATION DURING INSUFFLATION ANAESTHESIA

BY

G. L. ZEITLIN, D. H. SHORT AND M. E. FIELDING

The London Chest Hospital and The Middlesex Hospital, London

SUMMARY

Carbon dioxide elimination during apnoea was measured in sixty patients undergoing diagnostic bronchoscopy. Paralysis was maintained using suxamethonium after thiopentone induction of anaesthesia. In forty patients a 50 per cent mixture of nitrous oxide and oxygen was insufflated by nylon catheter in the trachea at a rate of 10 l./min. The mean quantity of carbon dioxide eliminated was approximately 20 ml/min (range 0-0.8 per cent). In twenty patients without insufflation the corresponding rate was approximately 6 ml/min (range 0-0.25 per cent). The relationship of this finding to the known effect of the heartbeat in producing a small amount of alveolar ventilation is discussed.

Insufflation of oxygen into the lower trachea is an apparently satisfactory method of maintaining oxygenation in patients who have been anaesthetized and paralyzed for diagnostic bronchoscopy (Cheatle and Chambers, 1955; Frumin, Epstein and Cohen, 1959).

It is generally believed that carbon dioxide elimination under these circumstances is poor or absent and the work of Cheatle and Chambers (1955) supports this belief. They insufflated oxygen at a rate of 3 l./min into the tracheas of five patients paralyzed with suxamethonium and undergoing bronchoscopy. The arterial carbon dioxide tension ($P_{CO_2}$) rose in all of them but at a rate which varied from 0.9 to 9.3 mm Hg/min in different patients. This rate of rise of arterial $P_{CO_2}$ is of the same order as that found by other investigators (Frumin, Epstein and Cohen, 1959; Eger and Severinghaus, 1961) during apnoea without insufflation.

There is evidence available to show that the heartbeat gives rise to a small amount of alveolar ventilation (West and Hugh-Jones, 1961; Dalsstrom, Murphy and Roos, 1954; Nunn and Hill, 1960) and it is therefore possible that during apnoea some carbon dioxide might reach the carinal area. If this is so then it is also possible that this might be eliminated by a higher insufflating flow rate than is commonly used.

We have therefore measured the volume of carbon dioxide that is eliminated, or "washed out", by the flow of gas of 10 l./min that we usually insufflate during anaesthesia for diagnostic bronchoscopy.

METHOD

On arrival the patients were seen in order to assess their fitness for general anaesthesia. They were given intramuscular atropine 0.9 mg, 30 minutes before the bronchoscopy. Each patient was brought to the theatre wearing a plastic face-piece with oxygen flowing into it at a rate of at least 6 l./min. Anaesthesia was induced with 2.5 per cent thiopentone solution in a dose varying between 12 and 20 ml; this was followed by suxamethonium 100 mg. A well-lubricated nylon intravenous catheter (30 cm long, FG8, external diameter 2.76 mm) was passed into the trachea. Its proximal end was connected to a Boyle machine with the Rotameters set at 5 l./min. Each of nitrous oxide and oxygen. This catheter normally allows the passage of a gasflow of 10 l./min. Occasionally during use its orifice was partially occluded by the tracheal wall and smaller flows resulted.

For the purpose of the investigation a Magill tube was also inserted into the trachea and its proximal end connected by tubing of wide internal bore to a three-way tap. One exit from the tap led to an empty polyvinyl chloride bag of large capacity (100 l.). By turning the tap the endotracheal tube was connected to the bag for 1 minute. The endotracheal tube, but not the
catheter, was removed and the bronchoscopy then carried out.

The percentage of carbon dioxide in the washed out gas mixture in the bag was immediately measured with a Godart Capnograph infrared gas analyzer and the volume of the gases in the bag measured in a spirometer recording on a kymograph. This was done in forty patients. The arrangement of the apparatus is shown in figure 1.

The opportunity was also taken to investigate the question of whether any carbon dioxide appears spontaneously at the mouth of an apnoeic subject. Exactly the same method was used except that there was no insufflation and the collecting bag was previously filled with 5 l. of nitrous oxide and 5 l. of oxygen. This was done in twenty patients.

During the whole of each sample collection the abdomen was watched and the diaphragm palpated through it to preclude any respiratory movements. The bronchoscopist checked on the position of the catheter tip in twelve of the patients; in nine it was just inside one or other main bronchus and in the other three it lay in the trachea within 1 inch of the carina. The reading on the pressure gauge never rose more

![Diagram to show arrangement of apparatus.](image)

**Fig. 1**

The collision broadening effect of a 50 per cent nitrous oxide and oxygen mixture on the indicated carbon dioxide concentration.

**Fig. 2**
than 0.5 cm H₂O above atmospheric and thus the bag acts as a valid model of the atmosphere in that it creates virtually no positive pressure in the system. The bag was shown to be gastight to carbon dioxide for at least 1 hour by passing consecutive samples from a mixture of carbon dioxide in 50 per cent nitrous oxide and oxygen previously placed in it, through the analyzer at intervals over such a period. No change in carbon dioxide concentration was indicated by the Capnograph meter.

The collision broadening effect (Bergman, Rackow and Frumin, 1958) on the Godart analyzer of a 50 per cent nitrous oxide and oxygen mixture gives a reading (in the range zero to 1 per cent carbon dioxide) which is 0.15 to 0.20 per cent high. The effect is illustrated in figure 2 and our experimental readings were appropriately adjusted. The scale of the analyzer meter can only be read to the nearest 0.05 per cent carbon dioxide. We tried to minimize this potential inaccuracy by having each reading agreed by two persons. The analyzer is set up every day by the use of its internal electrical calibrating system and it is regularly set to agree to within 0.05 per cent carbon dioxide of the reading given by the Haldane apparatus. It gives a linear reading up to 9 per cent carbon dioxide.

The patients for the investigation were chosen at random from those attending the out-patient bronchoscopy clinic, but those who were not considered fit enough to withstand an extra 2 minutes of anaesthesia were excluded.

RESULTS

In the forty apnoic patients in whom insufflation was carried out the average carbon dioxide concentration in the bag was 0.2 per cent (range 0–0.8 per cent), after correcting for the collision broadening effect. Results are shown in figure 3. The average volume of gases collected was 9.9 l. (SD = 1.3); thus the mean quantity of carbon dioxide eliminated was approximately 20 ml/min.

In the twenty patients who were apnoic but in whom no insufflation was carried out an average reading of 0.06 per cent carbon dioxide (range; zero to 0.25 per cent) was obtained. This is equivalent to an average elimination of 6 ml of carbon dioxide per minute.

DISCUSSION

These results therefore confirm previous observations that endotracheal insufflation of gases, even at the high flow rate used in the present work, has very little effect in preventing the accumulation of carbon dioxide in the body during apnoea. Assuming an average production of 158 ml CO₂/min under basal conditions by men of the age group (40–80) that was investigated (Shock and Yiengst, 1955), then this method only removes one-eighth (20/158) of this amount.

The results of our second investigation also support the following statement by Holmdahl (1956): "... experimental and theoretical support is presented for the view that the gas
stream into the lungs, due to the haemoglobin oxygen pump, during a 1 hour period of apnoeic diffusion oxygenation is strong enough to prevent diffusion of measurable amounts of carbon dioxide from the lungs to the outside air". But the finding that by insufflation definite, albeit small, amounts of carbon dioxide are removed during apnoea is of some theoretical interest. It means that small amounts of carbon dioxide do reach the carinal area during apnoea, and this is probably the result of the effect of the heartbeat in producing some alveolar ventilation. West and Hugh-Jones (1961) demonstrated the phenomenon of pulsatile gasflow in the bronchi caused by the heartbeat, using their bronchial flowmeter. Although their patients were awake and breathing spontaneously while undergoing bronchoscopy under local anaesthesia there is no reason to think that the effect is any different in an apnoeic patient. Nunn and Hill (1960) during an investigation of respiratory deadspace noted that during periods of apnoea, with each heartbeat there was a sharp rise in the concentration of carbon dioxide in the gas sampled from the region above the carina. Sometimes the carbon dioxide concentration almost reached the alveolar plateau level and it was apparent that there must have been considerable movement of gas. Dahlstrom, Murphy and Roos (1954) suggest that the effect is due to the change in volume of the lung vessels with each heartbeat.

From the figures given by Frumin, Epstein and Cohen (1959) and Eger and Severinghaus (1961) the mean rate of rise of arterial $P_{co2}$ in apnoeic anaesthetized man is 3.8 mm Hg/min. The method of high-flow endotracheal insufflation described here, in eliminating approximately 13 per cent of the metabolically produced carbon dioxide, would be expected to reduce this rate of rise to 3.3 mm Hg/min.

ACKNOWLEDGMENTS
We must thank Dr. L. H. Capel for much guidance as well as providing us with the facilities for measurement; Miss E. C. Fletcher for considerable help; Dr. L. O. Mountford for his interest and the theatre and surgical staff for their co-operation.

REFERENCES


L’ELIMINATION DU GAZ CARBONIQUE DANS L’ANESTHESIE PAR INHALATION

SOMMAIRE
L’élimination du gaz carbonique en apnée a été mesurée chez 60 malades soumis à une bronchoscopie diagnostique. La paralysie a été maintenue en utilisant le suxaméthonium après l’induction de l’anesthésie au thiopentone. Chez 40 malades, on a insufflé dans la trachée par un cathéter de nylon un mélange à 50 pour cent d’oxyde nitreux et d’oxygène, à la vitesse de 10 l./min. La quantité moyenne de gaz carbonique éliminé était approximativement de 20 ml/min (entre 0–0,8 pour cent). Chez 20 malades sans insufflation, le taux correspondant était approximativement de 6 ml/min (entre 0–0,25 pour cent). On discute le rapport entre ce résultat et l’effet connu des battements cardiaques dans la production d’une petite quantité de ventilation alvéolaire.

KOHLENDIOXYDAUSSCHEIDUNG WÄHREND DER INTUBATIONSNARKOSE

ZUSAMMENFASSUNG

Bei 60 Patienten, bei denen eine diagnostische Bronchoskopie durchgeführt wurde, wurde während der Apnoe die Kohlendioxydausscheidung gemessen. Nach Einleitung der Narkose unter Verwendung von Thio- penton wurde die Paralyse mit Suxamethonium aufrechterhalten. Bei 40 Patienten wurde eine 50 prozentige Mischung von Lachgas und Sauerstoff bei einer Rate von 10 l/min durch einen Nylonkatheter in die Trachea eingeblasen. Die mittlere ausgeschiedene Kohlendioxydmenge betrug ungefähr 20 ml/min (Bereich 0–0,8 Prozent). Bei 20 Patienten ohne Insufflation betrug die entsprechende Rate ungefähr 6 ml/min (Bereich 0–0,25 Prozent). Die bekannte Wirkung des Herzschlages für die Erzeugung einer geringgradigen Alveolarventilation wird unter Bezug auf diese Befunde diskutiert.