CONTINUOUS OBSERVATION OF AVERAGE EXPIRATORY CO_2 DURING ANAESTHESIA BY THE 'CARBOVISOR'

by

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In a recent review [2] on the suitability of controlled respiration for the maintenance of a near-normal physiological state during anaesthesia, SEEVERS [4] is quoted as saying: 'It is probably true that a busy anaesthetist, even the most expert, has difficulties with carbon dioxide almost every day of his life and uses narcotic concentrations of this gas intermittently, or in some instances regularly, whether he is aware of the fact or not'.

If the patient is receiving high oxygen mixtures his arterial oxygen saturation may be satisfactory with poor ventilation and severe hypercapnia, the usual CO_2 excited warning signals being absent in deep anaesthesia; extensive literature on this problem can be found in the reviews cited [2, 4].

On the other hand, acapnia by hyperventilation, although its bad effects may have been over-emphasized by Y. HENDERSON, certainly causes a vasoconstrictive reduction of cerebral blood flow by 40 per cent or more [3], besides many other cardiac and circulatory reactions.

It must therefore be obvious that, in addition to oximetric controls, it is desirable to have some means of observing the CO_2 content of, say, the patient's average expiratory air during anaesthesia.

Instruments which indicate the CO_2 content of gas mixtures are available in many designs, but they do not appear to have much application under the conditions, prevailing in the operating theatre.

In some investigations [4], alveolar p_{CO_2} has been calculated from the pH and total CO_2 taken from arterial blood samples. This demands an accuracy of 0.01 pH, which is rarely obtainable.

For stability, simplicity of design and manipulation, we can recommend the 'carbovisor', which we have thoroughly tested clinically. † It enables the anaesthetist

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† To be obtained from KIPP, Delft, Holland.

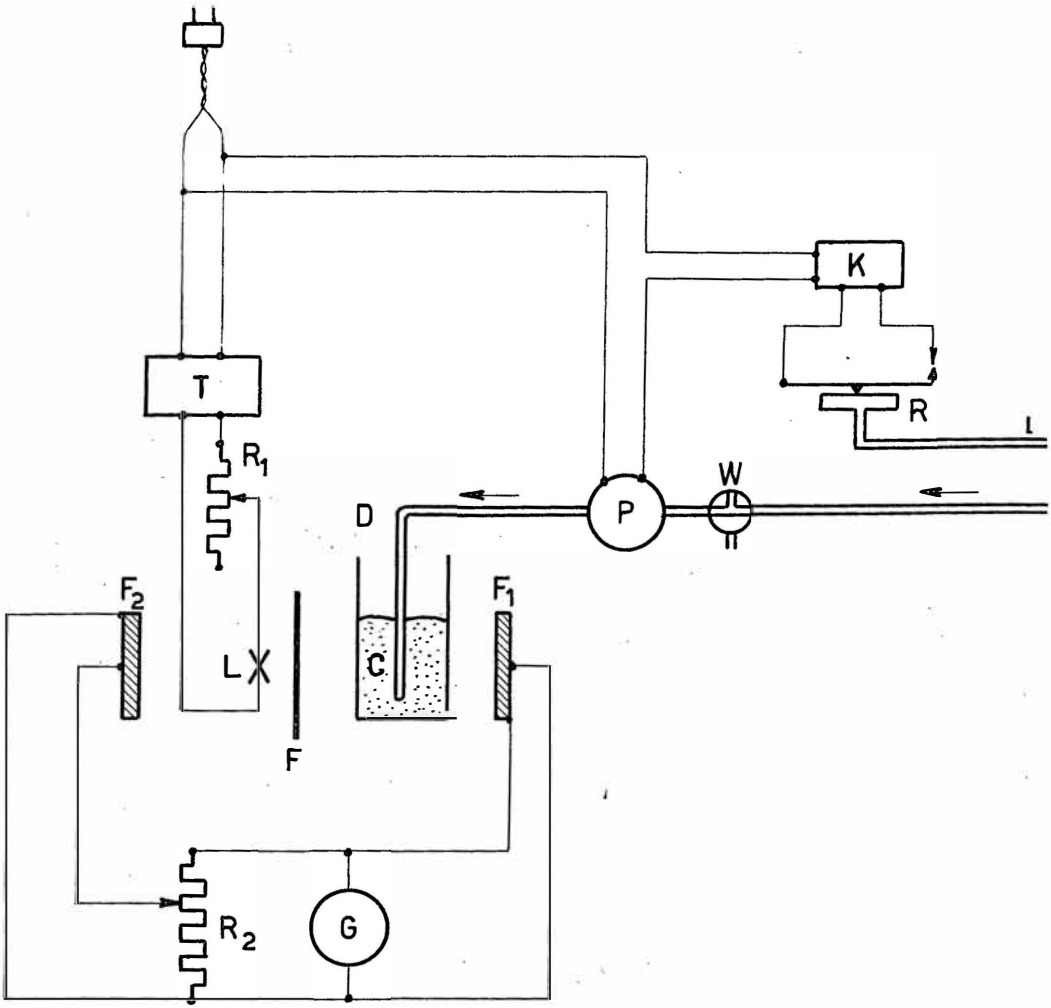

Fig. I

to read continuously the average CO_2 content of expired air during anaesthesia, with a lag of about a minute and an accuracy of about 0.2 per cent.

In the carbovisor, a small stream of air is aspired intermittently from the breathing circuit, *e.g.*, from the tracheal tube during expiration. This air is dispersed through an indicator solution, the change in colour of which is registered photo-electrically. There is a linear relationship between the CO_2 content and the galvanometer deflection up to 12 per cent of CO_2.

The assembly, consisting of aspiration and dispersion pump, indicator cuvette with dispersing tube, photo-electric arrangement with stabilizer and compensating cell, and tambour-relay compound for inspiratory blocking, is built inside an A 70 KIPP portable galvanometer. Calibration and management are rapid and simple.

The apparatus is sketched in *Figs. I* and *II*.

The patient's air is aspired through a suitable length of light rubber tube, and enters the small vibrating membrane pump (P) (I, II) at (a) (II), leaving it at (b) (II) and entering the dispersing tube (D) (I, II) at (c) (II). It passes in fine bubbles through the upper part of the lucite cuvette (C) (I, II), which is filled with the indicator solution; from there the air escapes.

For determination of the plasma alkali reserve the circuit is closed by covering the cuvette with a disc and connecting it by tube to the pump inlet (a).

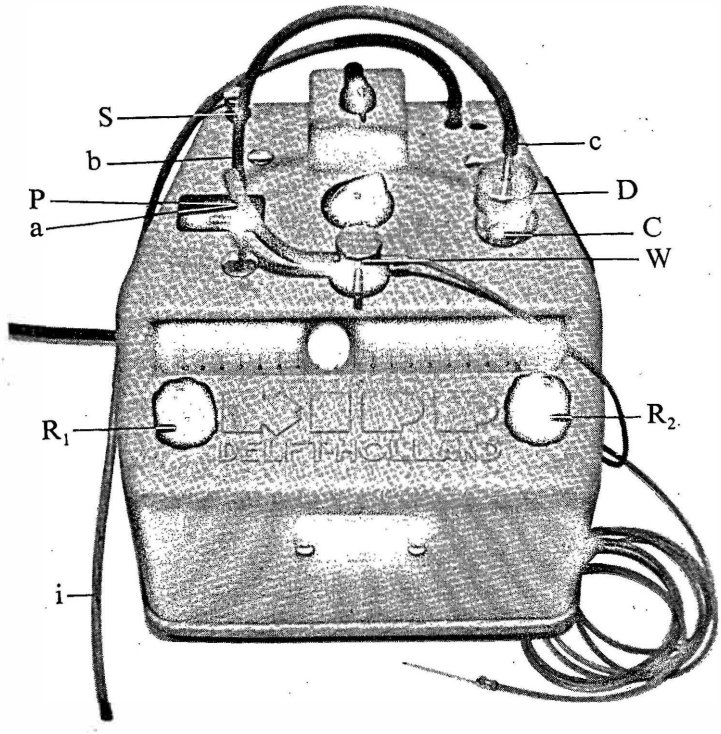

Fig. II

The indicator solution (0.005 per cent of bromthymolblue in 0.05 per cent $NaHCO_3$) is in the lower, non-aerated part transilluminated by a small lamp (L), through a suitable filter (F, Ilford No. 281). The agitation in the tube is such that rapid mixing is effected.

The intensity of aspiration and aeration can be regulated by the screw (S) (II). Foaming is effectively prevented by covering the upper part of the lucite cuvette wall with a thin layer of antifoam silicone grease.

If the indicator solution is greatly aerated it must be renewed every three hours. If the cuvette is newly filled with the indicator solution from the storage bottle, it is advisable to pass air through it for a few minutes, followed by a CO_2 mixture also for a few minutes. After returning to air the solution is ready for use.

The transmitted light is received on the barrier layer photo cell (F_1) (I), which is connected with a compensating photo cell (F_2) (I), and the galvanometer (G) (I). The heating current from the stabilized transformer (T) (I) can be adjusted by the resistance (R_1) (I, II), and the compensating photo cell current by (R_2) (I, II).

Slight inflation of the tambour (R) (I), by pressure through the inlet (i) (I, II), will activate a relay (K) (I), thus disconnecting the electrical pump circuit and preventing inspirational aspiration. The sensitivity of this arrangement can be adjusted so that aspiration is stopped exactly at the beginning of inspirational positive pressure.

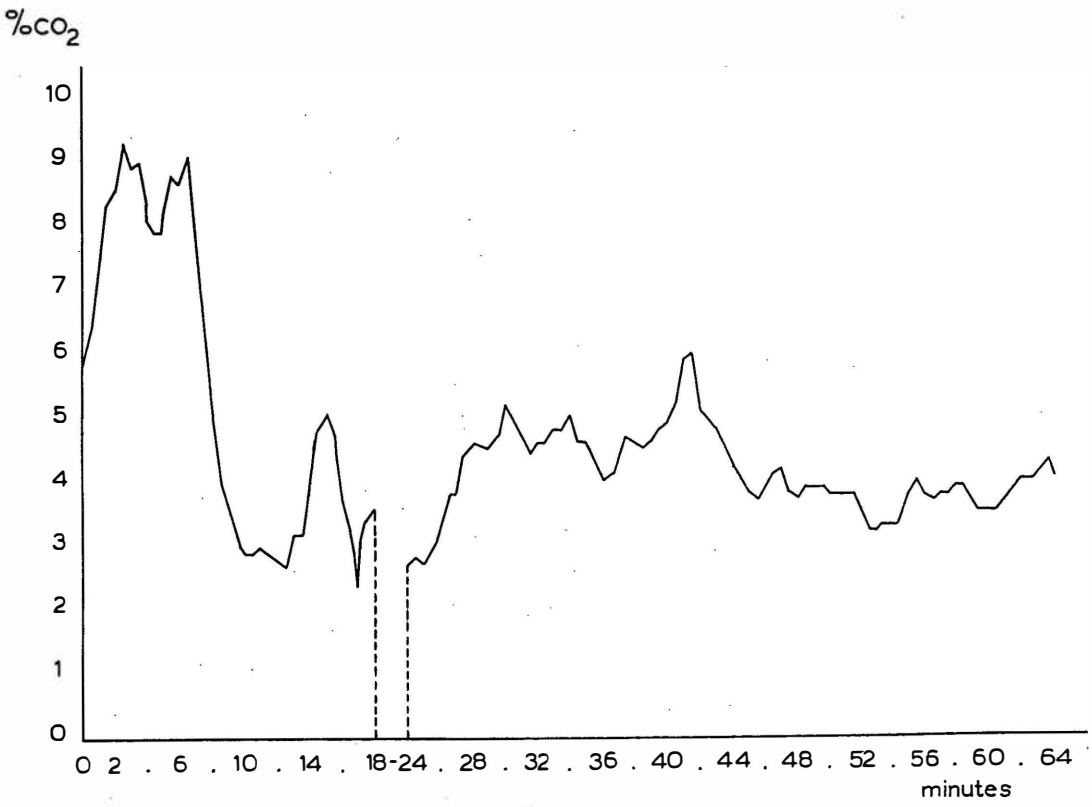

Fig. III

The 3-way tap at (W) (I, II) enables the observer to aspire the patient's air or another gas mixture at will for calibrating purposes.

Calibration and measurement

(1) The galvanometer is adjusted to left—zero and shunted to sensitivity 2.

(2) Room air (CO_2 zero) is dispersed through the indicator solution; the compensation current is switched off by turning R_2 counterclockwise as far as possible and the lamp heating current is adjusted by R_1 so that the photo cell current is brought to a predetermined value.

(3) The predetermined value is found by (*a*) compensating the zero CO_2 current to galvanometer zero at sensitivity 3, by adjusting R_2; (*b*) dispersing a gas with known CO_2 content through the indicator solution for a few minutes; (*c*) adjusting the lamp heating current by R_1, so that 1 per cent of CO_2 is indicated by 2 cm galvanometer deflection at sensitivity 3; (*d*) reading the deflection at sensitivity 2, zero CO_2, uncompensated.

(4) If the galvanometer is at sensitivity 3, indicating zero CO_2 by 0 cm and say 5.0 per cent CO_2 by 10.0 cm, it will indicate linearly up to 12 per cent CO_2.

(5) By means of a small light rubber tube of suitable length the pump inlet is connected to the patient's tracheal tube or to some other suitable place by the tap (W), so that at any moment aspiration can be changed over from room air to the patient's air.

(6) By means of a similar tube the inlet (i) of the interruptor is connected to a suitable place in the ventilating apparatus, so that positive inspiratory pressure will disconnect the vibration pump, and aspiration only occurs in the expiratory phase.

(7) If observation is prolonged for more than an hour, the zero CO_2 position must be controlled and readjusted occasionally by R_1, and at the end by checking with a known CO_2 percentage.

As stated above, controls may be made easily and frequently by dispersion of room air and of a known CO_2 percentage. Controls with samples, taken from the patient during anaesthesia and measured by gas analysis, have shown satisfactory agreement.

An example of expiratory CO_2 during anaesthesia, giving the value of CO_2 control, is shown in *Fig. III.*

The case was that of a 63-year-old woman, undergoing cholecystectomy; she was anaesthetized with the DRAEGER apparatus intratracheally by hand ventilation. Pentothal, curare, O_2–N_2O. Expiratory CO_2 rose quickly to 9 per cent, and decreased when—after six minutes—hand ventilation was made much more intensive. When this calmed down somewhat after twelve minutes, CO_2 started to rise again, and had to be lowered once more by hyperventilation. This was repeated after thirty-eight minutes, but finally the right degree of ventilation was established. Zero control between eighteen to twenty-four minutes.

Summary

Description of the 'Carbovisor', which enables the anaesthetist continuously to observe the patient's expiratory CO_2.

Résumé

Description du 'Carbovisor,' un appareil permettant à l'anesthésiste de suivre le taux de gaz carbonique de l'air expiré par le malade.

Zusammenfassung

Beschreibung des Apparats 'Carbovisor,' der es dem Narkotiseur ermöglicht, den CO_2-Gehalt der Ausatmungsluft des Patienten zu verfolgen.

Samenvatting

Beschrijving van de 'Carbovisor,' die het de narcotiseur mogelijk maakt het CO_2 gehalte van de uitademingslucht van de patiënt continu te observeren.

References

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4. SEEVERS — *New York State Journ. of Med.* 1944 (597)