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THE T-PIECE TECHNIQUE

BY

PHILIP AYRE

From the Department of Anaesthetics, Newcastle upon Tyne

SINCE the T-piece technique was first described nearly twenty years ago (Ayre, 1937) various criticisms and modifications have been suggested from time to time, and the present moment may be opportune for a brief appraisal of the situation before the essential simplicity of the original technique becomes irretrievably lost in a tangled web of expiratory valves and corrugated tubing.

Primarily intended for endotracheal anaesthesia of infants and young children undergoing operation for the repair of hare-lip and cleft palate, the T-piece (fig. 1) consists of a light metal tube 1 cm in diameter, into which nitrous oxide-oxygen supplemented by minimal ether is "injected" through a small inlet tube at right angles to the main limb. One end of the T-piece is connected to the endotracheal tube, while the other end is left open to the air: a length of rubber tubing attached to the open end constitutes a small reservoir for the anaesthetic gases, most of which would otherwise escape into the outside air. The internal diameter of the reservoir tube should be 1 cm (area of cross-section 0.78 sq.cm), so that each inch in length will have a capacity of approximately 2 ml. For adults, a slightly larger tube may be used with an internal diameter of $1\frac{1}{4}$ cm and a capacity of 3 ml per inch (2.5cm) in length. There is no practical advantage in exceeding these measurements, and corrugated rubber tubing should not be used as a reservoir tube because of the greatly increased "dead space" present.

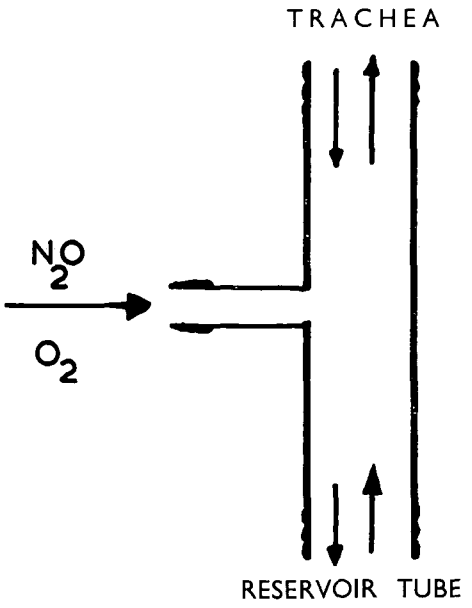

FIG. 1
Diagram of T-piece

RATE OF FRESH GAS INFLOW

It is commonly supposed that with a system open to the air there must be some dilution of the anaesthetic gases inhaled by the patient. While this may be perfectly true, and sometimes even desirable, it is possible, by increasing the flow of nitrous oxide and oxygen, to exclude air altogether from the system and thus achieve genuine

gas-oxygen anaesthesia without air dilution. It might be thought that the comparatively high flow rate required to exclude air would be unduly extravagant and wasteful of nitrous oxide; but the following simple calculations will show that this is not necessarily so, especially where babies and children are concerned.

In order to exclude air from the inspired gases the flow of nitrous oxide and oxygen from the Boyle's apparatus must be at a rate which will satisfy the minute volume requirements of respiration. As the average duration of the inspiratory phase of respiration is only one-third of the time taken for a complete respiratory cycle the total fresh gas inflow into the T-piece must be at least three times the minute volume of the patient. This high rate of gas inflow would in most cases be very extravagant, but by incorporating a reservoir tube on the open end of the T-piece a much lower flow rate will be sufficient. Thus, if the capacity of the reservoir tube is equivalent to one-third of the tidal volume of respiration, the flow of nitrous oxide and oxygen may be correspondingly reduced (by one-third) to twice the minute volume. In clinical practice a fresh gas inflow of $1\frac{1}{2}$ to 2 times the minute volume of the patient will usually ensure that there is no dilution of the inspired anaesthetic gases. To avert criticism from outraged physicists, it should be explained that these computations are only approximate, and are intended to illustrate the general principles affecting gas flow into the T-piece.

ELIMINATION OF EXCESS CARBON DIOXIDE

Providing the fresh gas inflow into the T-piece conforms with the principles enumerated in the preceding paragraph, there should be no rebreathing or appreciable retention of carbon dioxide in the reservoir tube. For example, if the cubic capacity of the reservoir tube is roughly equivalent to one-third of the patient's tidal volume, it follows that during the expiratory phase of respiration two-thirds of the tidal volume will be exhaled into the outside air and will pass completely out of the system. The expired gases still remaining in the T-piece and reservoir tube will be so diluted and displaced by the incoming flow of anaesthetic gases from the Boyle's apparatus that the percentage of carbon dioxide ultimately remaining in the system will be very small. Clinically, this is borne out by the quiet and effortless respiration normally seen when the T-piece is used.

In comparing various methods of nitrous oxide-oxygen administration, Woolmer and Lind (1954) claim that elimination of carbon dioxide is inefficient when the original T-piece technique is used, and state that they found a carbon dioxide content of 2.7 per cent in the reservoir tube. As the tube used in their experiments consisted of corrugated rubber tubing with a capacity of 550 ml—about four times the normal capacity, even for adults—their investigations appear to be somewhat wide of the mark, so far as the present technique is concerned.

EXPERIMENTAL INVESTIGATION OF THE T-PIECE

Although from a clinical point of view the T-piece technique has given highly satisfactory results during the last twenty years, it must be admitted that the exact

composition of the inspired gases has been a matter for conjecture, some anaesthetists holding the view that so much air enters the system that the anaesthetic effect of the nitrous oxide is negligible. Recently, Professor Pask suggested that experiments should be carried out to determine the degree of dilution present in the inspired gases, together with the carbon dioxide content, and thus provide a more rational basis for the administration of anaesthesia by this method. The experimental investigations were carried out by Dr. John Inkster, First Assistant in the Department of Anaesthetics, who was able to reproduce the working conditions of T-piece anaesthesia in the laboratory: as a result of which it was possible to carry out gas analysis at leisure, and without the disturbing prospect of a subsequent coroner's inquest on the patient.

Two interesting and important pieces of information emerged from the experimental investigations, which are described elsewhere in this issue:

(1) When the fresh gas inflow into the T-piece reaches a critical ratio, the concentration of nitrous oxide and oxygen in the inspired gases is maximal and there is no dilution by air. According to varying conditions the ratio ranges from $1\frac{1}{2}$ to $2\frac{1}{2}$ times the minute volume, which corresponds with the theoretical calculations made earlier in this paper.

(2) If the capacity of the reservoir tube does not exceed one-third of the tidal volume, there is no increase in the "effective dead space", and no excess carbon dioxide will be present in the inspired gases. This holds good when the fresh gas inflow is not less than $1\frac{1}{2}$ times the minute volume.

As it is unlikely that facilities will be available for estimating the tidal volume and minute volume of each patient, the figures given in standard textbooks of physiology may be used as a basis for calculating the required rate of flow for nitrous oxide-oxygen when using the T-piece. It should be remembered that normal respiration can vary greatly under different conditions, especially in infancy; but the figures given by Hall (1955) for babies and children up to the age of 8 years are very helpful, as they are the result of observations made under general anaesthesia.

The following table may be used as an approximate clinical guide to the gas inflow and reservoir capacity required for children of different ages. The term "gas inflow" includes both nitrous oxide and oxygen, the average percentage of oxygen ranging from 100 per cent for a small infant to 25–30 per cent for older children.

Age	Gas inflow (litres/min.)	Capacity of reservoir tube (ml)
0–3 months	3–4	6–12
3–6 months	4–5	12–18
6–12 months	5–6	18–24
1–2 years	6–7	24–42
2–4 years	7–8	42–60
4–8 years	8–9	60–72

T-PIECE ANAESTHESIA FOR ADULT PATIENTS

Although other methods of nitrous oxide-oxygen administration will usually be more suitable for adult patients, the T-piece may sometimes be used in certain operations in the region of the head and neck, where it is important to reduce vascular congestion to a minimum: such

operations include the removal of a brain tumour and other neurosurgical procedures, and also many E.N.T. operations. In these cases a fresh gas inflow of 12–15 litres/min, with a reservoir tube capacity of 150 ml, will be required to prevent dilution of the anaesthetic gases; but in many instances a much smaller flow of 6–9 litres/min, with a reservoir tube capacity of 72–84 ml, will provide adequate anaesthesia, especially when the patient has been premedicated with morphia or a barbiturate. Under these conditions, a moderate degree of air dilution will have no serious effect on the general level of anaesthesia, and may be preferable to using an extravagantly high flow of nitrous oxide. Trichlorethylene, or other volatile anaesthetic, should of course be used to supplement the nitrous oxide and oxygen.

SUMMARY

In writing this account of the clinical aspects of the T-piece technique, it is hoped that some of the questions often asked concerning the rationale and practical details of administration have been answered. No reference has been made to other "modifications" incorporating the principle of the T-piece, because it is felt that they are outside the scope of the present article. The T-piece technique is presented as a simple and trouble-free method of endotracheal anaesthesia especially suitable for infants and young children. Owing to the absence of a rebreathing bag and expiratory valve, there is virtually no resistance to respiration and vascular congestion is reduced to the minimum. The small capacity of the "reservoir tube", which can be adjusted to proportions suitable for the tidal volume of the smallest infant, effectively prevents any increase in the "dead space", so that the carbon dioxide content of the inspired gases is for all practical purposes within normal limits. Last, and perhaps not least, the T-piece technique is safe and easy to use.

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SOCIETY NEWS

GLASGOW AND WEST OF SCOTLAND SOCIETY OF ANAESTHETISTS

The above Society has the following programme arranged for 1956–57:

Saturday, October 20, 1956.
Joint Meeting with Association of Anaesthetists of Edinburgh, to be held in Edinburgh.

Friday, November 16, 1956.
Dr. R. Woolmer (Bristol): "The Investigation of Anaesthetic Problems."

Tuesday, January 22, 1957.
Dr. E. B. Hendry (Western Infirmary): "Fluid Balance Associated with Anaesthesia."

Thursday, February 21, 1957.
Members' Night.

Thursday, March 21, 1957.
Presidential Address: Dr. A. M. Brown.

Friday, May 3, 1957.
Annual General Meeting.

The Meetings are held at the Royal Faculty of Physicians and Surgeons, 242 St. Vincent Street, Glasgow, C.2, at 8.15 p.m. Tea is served from 7.45 to 8.15 p.m.