THE RESISTANCE OF ENTONOX VALVES

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SUMMARY

The resistances of thirteen Entonox valves were measured. Although there was a wide variation between them, this is unlikely to interfere with their performance when used in labour. During the passage of continuous high flows, freezing occurred in two valves, causing a reduction in flow after 5 minutes. It is very unlikely that this would occur in clinical use. Measurements of the resistances of eight of the valves were compared using a static tube or a wide-bore needle to measure pressure changes. There was no significant difference between the two methods at flows of up to 100 l./min.

The resistance of the Entonox valve was an important factor in a study of the effects on ventilation of inhalation apparatus used in labour (Davies, Hogg and Rosen, 1974). Because there is no published information about the resistance of Entonox valves and variations between valves, measurements were made on thirteen valves in use in Cardiff.

METHOD

A continuous flow through each of thirteen valves was provided by a domestic vacuum cleaner (Electrolux). It was attached to a Rotameter which was calibrated for flows up to 300 l./min of air (correction factor for 50% nitrous oxide/50% oxygen=0.871 air flow; Macintosh, Mushin and Epstein, 1963. The Rotameter was connected by a 1-metre length of corrugated tubing to the Entonox valve. A wide-bore needle, connected to a water manometer, was inserted into the corrugated tubing between the valve and the Rotameter. The gas flow was controlled by a screw clip (fig. 1).

The measurement of the resistance of one Entonox valve gave rise to some difficulty. After approximately 5 min, while measuring flows of 200–300 l./min, ice formed over the outlet and it became difficult to obtain steady flows. As the ice formation on the tube increased, a greater pressure was necessary to obtain a particular flow rate. Measurements were made after pouring hot water over the apparatus and the readings were repeated at each flow at intervals of about 10–15 min, using a pressure transducer (Statham P23DB) connected to the wide-bore needle.

There was some doubt about the accuracy of measuring pressure through a needle. Therefore, eight of the Entonox valves (five being unavailable) were measured again with a static tube (Cotes, 1968) in place of the needle (fig. 2).

In addition, the resistance of the expiratory valve of an Entonox handpiece and, for comparison, a Cardiff Penthrane Inhaler handpiece were measured in series with a 1.5-metre length of corrugated rubber tubing.

RESULTS

The pressure-flow characteristics of each of the thirteen Entonox valves is shown in figure 3. The mean pressure-flow curve for all thirteen valves and the standard deviations of flow at each applied pressure are shown in figure 4.

The comparison between the mean pressure measurements of apparatus resistance made using a

![Fig. 1. Apparatus used to measure resistance of Entonox valves using a needle to measure pressure.](image-url)
needle inserted into the rubber tubing and a static tube is shown in figure 5. There was no significant difference between the two methods for any flow up to 100 l./min.

During the attempted passage of a continuous flow two Entonox valves showed a fall in flow at a steady pressure. In one valve this occurred after 4 min at a flow of 250 l./min, being accompanied by heavy ice formation over the valve and along about 25 cm of the corrugated rubber tubing (fig. 6). The result was reproducible five times out of six at intervals of 2–3 days. The other valve produced a similar flow-pressure pattern once but this could not be repeated 30 min later; after 6 min 2 sec at a flow of 250 l./min the pressure exceeded 32 cm H₂O and the flow fell to 15 l./min. Ice formed on six other valves after 4–7 min at 220–250 l./min flow but no change in flow or pressure occurred.

The flow-pressure curves for the expiratory valves of the handpiece of the Entonox and Cardiff Penthrane Inhaler are shown in figure 7.

![FIG. 2. Apparatus used to measure resistance of Entonox valves using a static tube to measure pressure.](image)

![Pressure Difference vs Flow](image)

**FIG. 3.** The resistance of thirteen Entonox valves.

![FIG. 4. The mean resistance (and SD) of thirteen Entonox valves.](image)

**FIG. 4.** The mean resistance (and SD) of thirteen Entonox valves.

![FIG. 5. The mean resistance of eight Entonox valves showing the effect of using a static tube and a needle to measure pressure.](image)

**FIG. 5.** The mean resistance of eight Entonox valves showing the effect of using a static tube and a needle to measure pressure.
The resistance of Entonox valves

There was a wide variation in resistance between the thirteen Entonox valves in everyday use. The majority of these valves (12 out of 13) do not conform with British Standard recommendations (British Standards Institution, 1968) which state that the resistance to gaseous flow on inspiratory demand shall give a pressure drop of not more than 5 cm H₂O for a continuous flow rate of 60 l./min, and not more than 15 cm H₂O for a continuous flow of 300 l./min. A closer tolerance should be possible, although mothers using inhalation analgesics during labour tolerate an inspiratory resistance even higher than the highest of any of these Entonox valves (Davies, Hogg and Rosen, 1974).

The reduction in flow in two valves associated with the appearance of freezing at abnormally high flows could not be due to the presence of water in the gas mixture since the freezing occurred on several occasions with different cylinders of nitrous oxide in oxygen; nor did the phenomenon occur when other valves were tested with the same cylinder of gas. Therefore the fault lay within the valve. The most likely explanation is that the second stage valve (fig. 8) did not open adequately because of a change in the characteristics of the sensing diaphragm caused by the extreme fall in temperature. There is a known variation in the consistency of the sensing diaphragm of valves (L. Cox, BOC Ltd, personal communication) which might account for the fact that only two valves out of thirteen showed a reduction in flow when freezing occurred. There remains the less likely possibility that small holes in the valve allowed air to be entrained at high flows during the artificial conditions of testing.

**DISCUSSION**

There was a wide variation in resistance between the thirteen Entonox valves in everyday use. The majority of these valves (12 out of 13) do not conform with British Standard recommendations (British Standards Institution, 1968) which state that the resistance to gaseous flow on inspiratory demand shall give a pressure drop of not more than 5 cm H₂O for a continuous flow rate of 60 l./min, and not more than 15 cm H₂O for a continuous flow of 300 l./min. A closer tolerance should be possible, although mothers using inhalation analgesics during labour tolerate an inspiratory resistance even higher than the highest of any of these Entonox valves (Davies, Hogg and Rosen, 1974).

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It is a common observation that ice forms on the outside of an Entonox valve during the use of the apparatus in labour. In clinical practice it is extremely unlikely that there would be any effect on flow since flows in excess of 200 l./min rarely occur. Indeed, during these experiments, it was only after 5 min that ice appeared.

The resistance of the expiratory valve of the Entonox apparatus was relatively small and compared favourably, especially at high flows, with that of the expiratory valve of the Cardiff Penthrane Inhaler (fig. 7).

Finally, it does not appear to be essential to use a static tube to measure pressure changes when flow can be assumed to be fully turbulent (at high flow rates); a needle inserted into the tubing provided comparable results. However, in detecting small changes in pressure at low flows a static tube should give more reliable results; a needle may give false readings as a result of turbulent flow at the periphery of the gas stream.

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Book Review

This unpretentious manual contains, as might be expected of its editor, a vast amount of fact regarding obstetric practice and is a comprehensive résumé of the various analgesic and anaesthetic techniques which may be used in most obstetric situations. The better the wine the more critical the palate; thus anomalies are discernible even with such expert authors.

Much space is devoted to the use of both intermittent and continuous general anaesthesia for normal delivery and this includes the use of 100% N₂O for short periods, timed by stop-watch, whilst “open drop” methods receive attention in surprising detail. Neuroleptanaesthesia also receives much attention which smacks a little of dangerous polypharmacy, especially when small doses of non-depolarizing relaxants are recommended for perineal relaxation. The statement is made that these drugs will have little effect on the maternal respiration, but this is debatable, especially when fentanyl has been used for induction and continued incrementally to produce analgesia with the patient breathing spontaneously. The use of small doses of relaxants (6-9 mg of tubocurarine or 40-60 mg of suxamethonium) as supplements to inhalational anaesthesia is also advocated for operative vaginal delivery, although this is followed by the statement that inhalation anaesthesia should not be used if there is a risk of vomiting and aspiration. It would seem wiser to state that all these patients are susceptible to vomiting or regurgitation and inhalation and that either a regional technique or general anaesthesia with intubation is safer at all times.

Finally, there is a recommendation to use 2-3% halothane with IPPV to reduce tetanic uterine contractions and allow internal version and extraction. In the reviewer’s opinion this concentration of such a potent agent would cause anxiety even to experts in obstetric anaesthesia. However, the manual advises that only with higher concentrations should the maternal pulse and arterial pressure be monitored to detect cardiovascular depression.

It is easier to criticize a comprehensive monograph of this type than to edit the various individual contributions of experts in their field so that a balanced picture is presented for readers of varying expertise and knowledge. The anomalies that occur are minor but are important because of the wide range of potential readers. There is so much good information and technical advice in every chapter that this book should be read by every anaesthetist involved in obstetric analgesia and/or anaesthesia.

One would hope that in less well endowed parts of the world, lesser qualified personnel would be supervised closely when practising some of the techniques described and that they would be prevented from using others.

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