MODIFIED BEAVER RESPIRATOR

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A simple modification to the well known Beaver Respirator is described below. This introduces a negative phase into the cycle. With the exception of a simple ring adapter all standard parts were used throughout, although certain junctions had to be filed down to fit.

The inlet valve was removed and fresh gases introduced at the patient's end (fig. 1H), utilizing a standard Waters canister (fig. 1G) and connection. The rebreathing bag of the Waters canister was removed and replaced by a length of corrugated tubing (D) connected to the mount (E) bearing the manometer tube. This manometer mount was connected by the specially made ring adapter (F) to the end of the Waters canister.

The other end of the corrugated tube (D) was connected to the patient's port of the inspiratory-expiratory valve (C). The machine port of valve (C) was connected by the short length of corrugated tubing (B) to the outlet of the machine (A).

The outlet port of valve (C) was connected by a rebreathing bag mount (I) to the machine port of a second inspiratory-expiratory valve (K), utilizing the spare valve supplied with the machine. The patient's port of valve (K) was connected by a short length of corrugated tubing (L) to the inlet mount (M) of machine. The outlet port of valve (K) was blocked with a rubber bung. A one gallon rebreathing bag (J) was attached to the bag mount (I).

The manometer was changed in position to be as near to the patient as possible. Although at the rear of the soda lime canister, the manometer is connected by nondistensible metal parts to the endotracheal tube—a Bullough's endotracheal connection being employed. In this position it will give a relatively true reading of the intratracheal pressures. The photograph (fig. 2) shows the complete arrangement.

WORKING OF THE MACHINE

The stroke volume, speed and positive pressure controls remain and work as before.

During expiration the initial recoil from the lungs is accommodated by the rebreathing bag (J). As the bellows expand the bag is emptied, then the bellows suck gases from the lungs and lower the pressure. The degree of negative pressure depends on the relationship between the amount of gases blown off during inspiration and the flow rate of new gases.

In the inspiratory phase a certain amount of gases escape from the pressure control valve. If this amount lost exceeds that which flows into the circuit, a negative pressure must be formed when the bellows reach maximum volume. The amount of negative pressure is thus controlled by altering the flow rate of incoming gases; an increase in flow rate reduces the negative pressure, a reduction in flow rate increases negative pressure.

A flow rate of 0.5 to 2 litres usually provides adequate negative pressure. A negative pressure of 15 cm of water may be obtained. The return from positive peak pressure to zero is rapid, from negative to zero is slow, thus profoundly lowering the mean pressure. The path of inspiration is shown by the continuous line in figure 1, and the path in expiration is shown by the dotted line.

It was decided to compare the intrathoracic pressure of the original and adapted machine. The machine was used on the same patient with a pressure swing of 15 cm H2O in each case—i.e. 0 to + 15 cm and -5 to +10 cm. The speed of inflation was the same.

A cinematograph film of the manometer was taken and a complete cycle of the machine under both sets of conditions analyzed. The manometer readings were then plotted against time and the
FIG. 1
Diagram of the modified circuit.

FIG. 2
Photograph of modified machine.
graph representing the changes in pressures drawn. This is shown in figure 3.

The mean intrathoracic pressure calculated from the film was 5.9 cm H$_2$O in the unmodified machine and 1.2 cm H$_2$O in the modified, a most significant reduction.

The modified machine has been used with success in routine operations, maintaining patients on nitrous oxide and oxygen (in the thiopentone-relaxant-pethidine-nitrous oxide method), also using air enriched with oxygen to maintain respiration in hibernated patients and in long term respiratory paralysis. The air supply is from a cylinder of compressed air. An oxygen flowmeter was used as one calibrated for air was not obtainable. The error is under 10 per cent.

In long term cases the use of a closed circuit with a small leak minimizes the problem of humidification, as moisture is conserved in the circuit. Some condensation occurs in the corrugated tube (fig. 1d) but the inspiratory-expiratory valves remain dry and function perfectly. They have needed no attention even after 72 hours of continuous use.

This machine must not be used with explosive gases.

ADVANTAGES OF A SUBATMOSPHERIC PRESSURE IN EXPIRATORY PHASE

A fit person compensates for intermittent positive pressure by increasing the venous pressure. At operation this raised venous pressure leads to a great increase of bleeding, especially troublesome oozing. A lowering of the mean intrathoracic pressure decreases greatly the haemorrhage, easing the operation and leaving a fitter patient.

The frail, the ill, and those upon whom hypotensive drugs have been used cannot compensate for the raised intrathoracic pressure. I.P.P. respiration may, in these cases, cause a precipitate drop in blood pressure due to the interference with the venous return.

The introduction of a subatmospheric pressure phase in these cases leads to an immediate increase in the venous return and an improvement in the blood pressure. I have, in these cases, seen the blood being sucked out of the larger veins during operation, while the pressure has been subatmospheric.

In the grossly emphysematous patient the elasticity of the lungs disappears and I.P.P. leads to gross dilatation of the lungs, interference with the venous return, and collapse of the patient.

A subatmospheric phase leads to rhythmical inflation and collapse of the lungs and restoration of the patient's condition. In these cases the lungs do not deflate by themselves and the rebreathing bag (fig. 1j) never fills, the lungs being emptied by the negative pressure exerted by the bellows of the machine.

SUMMARY

A simple, inexpensive modification of the Beaver Respirator is described. It introduces a subatmospheric phase, prevents the valves failing through condensation, and minimizes humidification problems in long term cases. A method of calculating intrathoracic pressure, the working, and use of the machine are also described.
ACKNOWLEDGMENTS

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REFERENCES


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patient lived for nine hours after the operation and inflation with oxygen was carried on during this period. On three occasions, at two, four and eight hours after the operation, he quite spontaneously showed signs of returning muscle tone and increased depth of respiration. These lasted for about five minutes on each occasion and he then relapsed into the picture of partial curarization that he had shown since the end of the operation. His B.P. was maintained until just before his death.

The story in this case was complicated by the fact that at operation there was some question of injury to the right pleura. Some six hours after surgery he developed clinical signs of a right haemo-pneumothorax which was confirmed radiologically. A needle was inserted into the right chest and a little air and some 36 ounces (1 litre) of bloodstained fluid were withdrawn. The air was not under tension.

At autopsy there was evidence of a pneumothorax on the left but not on the right, this again was not under tension. Both lungs showed areas of collapse and the growth was found to be extending into the posterior pericardium and the right lower lobe.

Any definite conclusions cannot, of course, be drawn from one case and the story of the second anaesthetic contains many other complicating factors. Yet this patient showed signs of neostigmine-resistant curarization for at least five hours after the final dose of curare and also the total dose of d-tubocurarine (35 mg) was considerably less than anticipated for a four-hour thoracotomy. One week previously the use of gallamine followed by neostigmine had not been attended by any unexpected reaction. If a deficiency of potassium was a cause of this condition the deficiency presumably arose as a result of failure to ingest enough food on account of his dysphagia. Should this have been the case then an abnormal response to the use of gallamine at oesophagoscopy would have been expected. His daily intake of potassium between the anaesthetic procedures was certainly adequate and the biochemical investigations reveal no abnormality. Unfortunately at no time during his stay in hospital was an e.c.g. taken. Certainly the magnitude of the surgical procedures undertaken shows great variation, but the patient's condition during the oesophagectomy caused no alarm and there is no obvious reason why he should have failed to respond to neostigmine at the end of the operation. There was no gross dehydration or evidence of electrolyte imbalance as is seen in cases of long standing intestinal obstruction and allied conditions.

In brief it is difficult to see that there was any deficiency of potassium in this patient to account for this sequela of the second anaesthetic.

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