Update in Anaesthesia

Paediatric drawover anaesthesia

Sarah Hodges
Correspondence Email: sarahhodges1911@gmail.com

Summary

The drawover system provides anaesthesia without requiring compressed gas. It is very robust, portable, compact and easy to maintain.

Even though it is challenging anaesthetising small babies with minimal equipment, the drawover system can provide a safe, robust, portable and cost effective system for anaesthetising babies and children.

INTRODUCTION

The drawover system provides anaesthesia without requiring compressed gases and is the most commonly used method for delivering anaesthesia wherever there is not a reliable supply of compressed gases.

The essential components of the drawover system are

- A vaporiser
- A self-inflating bag or Oxford inflating bellows
- Two valves.

BASIC PRINCIPLES OF USE

Air is the carrier gas, which can be enriched with oxygen if available. This is drawn by the patient's inspiratory effort through the vaporiser into the patient's lungs via a non-rebreathing valve. Drawover is a low pressure system and without the one way valves gas flow could occur in any direction. The valves ensure flow of air and oxygen through the vaporiser to the patient.

One of the earliest systems consisted of:

- EMO (Epstein-Mackintosh-Oxford vaporiser designed specifically for ether,
- Oxford inflating bellows with two one way valves
- Heidbrink valve at the patient end.

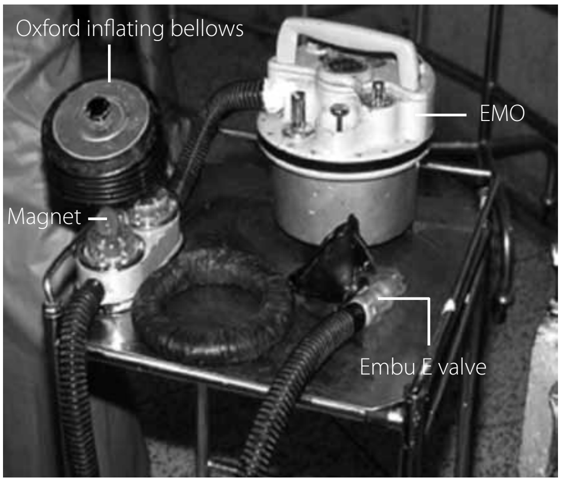

Figure 1. *A basic drawover system incorporating an EMO vaporiser*

Over the years the Ambu E valve was introduced to replace the Heidbrink valve. This enables both spontaneous and assisted ventilation but makes the second valve on the Oxford inflating bellows (OIB) redundant. There is a magnet which sits over the second valve to disable it when an Ambu E valve is being used.

The drawover system is very robust, portable, compact and easy to maintain and as it does not rely on a supply of compressed gases it is not only popular in developing countries but also with the military for battlefield anaesthesia.

The vaporisers used in drawover anaesthesia have a very low resistance. During anaesthesia the gas flow is intermittent (during inspiration with spontaneous ventilation and during expiration with assisted ventilation). The volume of air passing through the vaporiser is determined by the patient's tidal volume and respiratory rate. There may be huge variations depending on the respiratory effort and size of the patient. The dialled concentrations remain very accurate despite these massive variations.

The first drawover vaporisers were designed for ether. Characteristics of ether include:

- Low boiling point - 34°C
- High saturated vapour pressure - 56.6kPa
- Blood gas solubility coefficient (12) which is much greater than most commonly used volatiles like sevoflurane (0.9) and isoflurane (1.2)
- Both induction and wake up are slow
- Atropine is required in all patients due to the excessive salivation produced

Sarah Hodges
Mengo Hospital
PO Box 20146
Nakawa
Kampala
Uganda

- Respiratory stimulant
- Sympathomimetic
- Causes bronchodilatation
- Some analgesic effect at low doses
- Potentiates the effect of muscle relaxants
- Tends to increase blood glucose concentration, and to relax uterine muscle
- Gas induction is very slow as it is also a respiratory irritant. Increase the concentration by 1% every 6-8 breaths up to 10% and then increase it by 2.5% every 6-8 breaths up to 20%
- Maintenance concentration is 6-8% with spontaneous breathing and 2-4% if the patient is being ventilated.

Although ether was removed from the WHO essential drugs list in 2012, it is a useful and safe volatile anaesthetic especially in areas where oxygen is scarce or where there is no trained anaesthetic provider. There is a risk of explosion which is minimised when using only air as the carrier gas and in remote locations diathermy is rarely available. If diathermy is being used a safe distance of 20cm between the expired port and the diathermy should be maintained. Ether is heavier than air and a scavenging tube can be fixed to the expiratory port and dropped to the ground to minimize the amount ether around the surgical site.

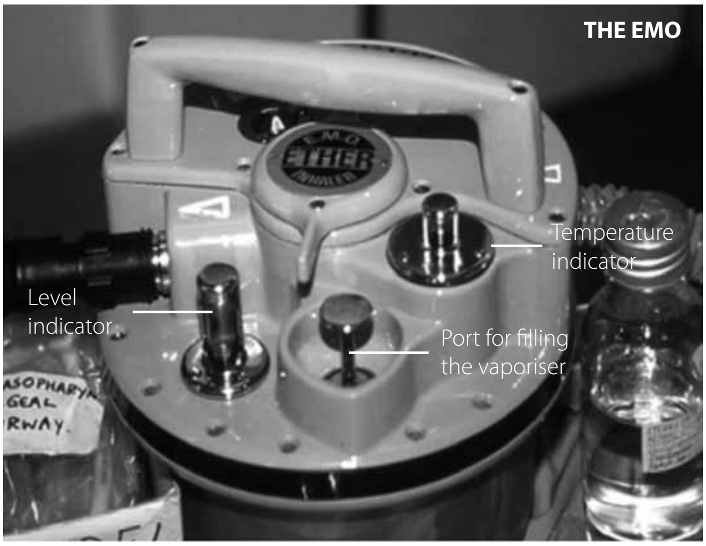

Figure 2. *The EMO vaporiser*

As such high concentrations are required to maintain anaesthesia, the EMO and "Afya" - the two drawover vaporisers designed for ether - are very bulky. The EMO is thermally buffered with a 1500ml water jacket and compensated with a small ether bellows and requires no keyed filling. The resistance through the EMO is only 0.5cm of water (= 0.049kPa) unlike a TEC 3 or TEC 4 vaporiser which has a resistance of 21-29cm of water (= 2.0–2.84kPa). It has cloth wicks which still contain 200mls of ether when the level indicator is empty. If the EMO is overfilled the wicks will be submerged and the output will decrease. It has a temperature indicator which is red when above 30°C, aluminium at less than 10°C and black at the optimal working temperature 10°C to 30°C. It produces very accurate concentrations with variable flow rates but loses precision with continuous flow and with extremely low flow rates.

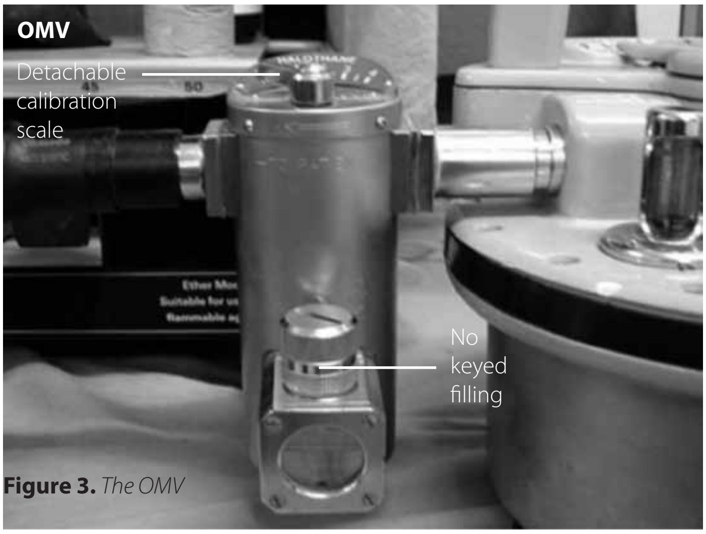

Figure 3. *The OMV*

A version of the Oxford miniature vaporiser (OMV) is used as part of the Triservice apparatus. Although the carrier gas flows from right to left in most drawover apparatus, in the triservice version of the OMV carrier gas flows from left to right. It is very compact with a capacity for 50ml of anaesthetic agent. It has a metal wick and is not thermally compensated but only thermally buffered with an ethylene glycol jacket. In the original design the downstream vaporiser was filled with trichloroethylene. The calibration scale can be detached allowing use of different inhalational agents, most commonly halothane. It is accurate with variable flow rates but this accuracy drops off in the continuous flow mode. As it is only thermally buffered, with prolonged and high gas flows the concentration decreases as the temperature decreases and you will see condensation appear on the outer surface.

The PAC vaporiser is another drawover vaporiser originally made with different models for ether, methoxyflurane, trichloroethylene and halothane. It is now only used for halothane. Some models have keyed filling. It is thermally compensated with a bimetallic strip. Its accuracy decreases rapidly when used with continuous flow and very low flows.

TECHNIQUE

In the standard drawover system the inspired oxygen concentration is determined by:

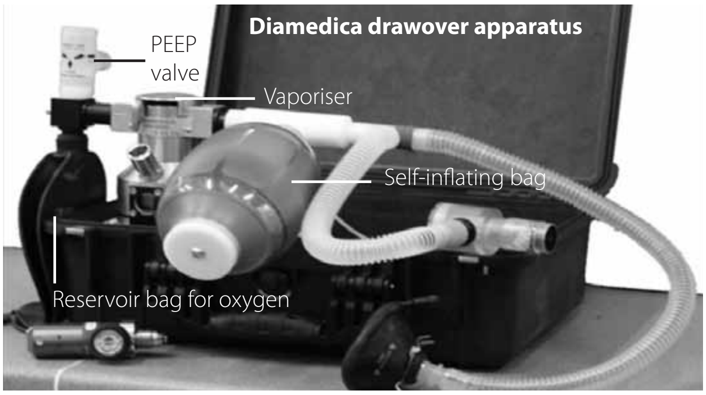

Figure 2. *The Diamedica drawover apparatus. In recent years this system has been incorporated into a more typical anaesthesia machine, the Glostavent*

- Total ventilation
- Oxygen flow rate
- Size of the reservoir tubing upstream of the vaporiser.

The respiratory rate and inspiration/expiration ratio have much less influence on the inspired oxygen concentration. If the reservoir tubing is short, with a volume of 104ml, then a high inspired oxygen concentration is impossible whatever flow rate is used. With a reservoir tubing of at least one metre in length and 415ml volume an inspired oxygen concentration (FiO_2) of 30% can be achieved with a flow rate 1L.min^{-1} and 60% with a flow rate of 4L.min^{-1} As air is the main carrier gas for the drawover system it is impossible to achieve 100% inspired oxygen concentration for pre-oxygenation unless you fill a large bag with 100% oxygen and attach it tightly to the reservoir tubing.

The portable Diamedica drawover system has overcome the limitation on inspired oxygen fraction by adding a reservoir bag which is constantly being filled with oxygen throughout the respiratory cycle.

Standard drawover systems have to be adapted for use in small children to overcome the deadspace and turbulence in the apparatus and the resistance in the valve. These all increase the work of breathing for small children and potentially cause alveolar collapse.

Mask induction, providing CPAP and pre-oxygenation are all more problematic with drawover anaesthesia in small children.

The other issue in paediatrics is the performance of the vaporiser. Generally the drawover vaporisers continue to be efficient at small tidal volumes as their output is affected more by a drop in temperature than tidal volume. With all the vaporisers except the recently designed ones, there is a noticeable loss of output with continuous flow.

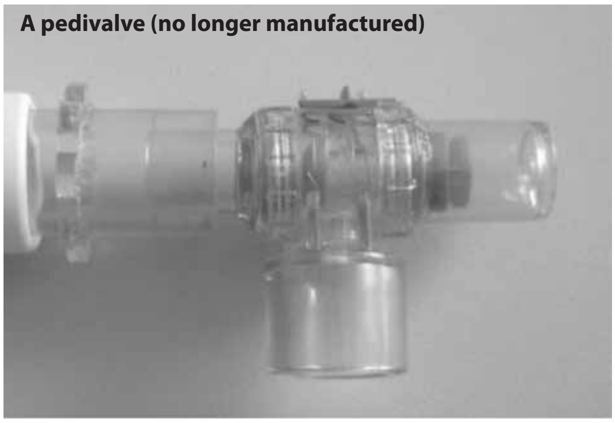

Figure 5. *Paediatric Drawover using a paedivalve, a small self- inflating bag and two OMV vaporisers as in the Triservice apparatus.*

In the earliest system everything was downsized except the EMO. There was a paediatric Oxford inflating bellows and a pedivalve instead of the standard Ambu E valve. A small self-inflating bag (SIB) can also be used to replace the Oxford inflating bellows.

Another way to use drawover in children is to convert it to a "manual continuous flow". Attach an Ayre's T-piece to the outlet of the Oxford inflating bellows (OIB) or self-inflating bag (SIB) which is attached to the outlet of the vaporiser (EMO, OMV, PAC). With the Oxford inflating bellows both valves are in use to ensure unidirectional flow as this is still a low pressure system. Compress the bellows about 6-8 times per minute with a rapid upward jerk and a slow downward movement. This sucks a flow of air and oxygen across the vaporiser and fills the bag on the T-piece which is used to ventilate the baby. The compression of the bellows has to be constant and continue in both spontaneous and assisted ventilation. A similar effect can be achieved with a self-inflating bag but as by its nature a self-inflating bag reinflates automatically with air 60 small squeezes per minute will achieve a tidal volume of approximately 100ml. It is important not to over compress the self-inflating bag as this will be transmitted to the baby's lungs and may cause overinflation. This "manual continuous flow" mimics adult drawover but the output of the vaporisers is not as expected. You will usually need to dial up a higher inspired concentration and is therefore less economical. It can be used when there is no oxygen or electricity but it is very labour intensive as one hand is pumping the bellows and the other ventilating with the Ayre's T-piece. This can make it difficult at induction especially if there is no assistance to the anaesthetic provider.

Another way of using the drawover apparatus in small infants is to convert it to simple continuous flow. This can be done using a Farman's entrainer:

- Fits into the distal end of any drawover vaporiser.
- Acts as a venturi entraining air as oxygen flows through at 2L.min^{-1}. This produces total flow approximately 10L.min^{-1} and FiO_2 35%.
- Oxford inflating bellows have to be closed but remain in circuit for their valves: this is still a low pressure system and flow could become bidirectional without the valves.
- Produces a continuous flow of air and oxygen so that the vaporisers markedly lose their accuracy: drawover vaporisers were designed for intermittent gas flow.
- Attach the side arm of the vaporiser to a mercury sphygmomanometer. Adjust the flow of oxygen until the manometer reads 100mmHg which is supposed to ensure a total flow of 10-12L.min^{-1}.

You can also produce continuous flow by simply attaching the oxygen supply directly onto the vaporiser and putting an Ayre's T-piece on the outlet of the vaporiser. This needs a high flow of oxygen and a one way valve between the vaporiser and the T-piece to prevent backflow and ensure filling of the bag on the T-piece. As with the Farman's entrainer the vaporiser will deliver significantly lower concentrations than expected.

In the newer designed systems with a reservoir bag attached to the inlet of the vaporiser, you can connect a T-piece with a one way valve directly to the vaporiser outlet or substitute a paediatric self-inflating bag for the adult one.

In situations where there is a lack of paediatric equipment it is safe to use the adult drawover equipment. You must ventilate all babies under 5kg body weight however short the procedure. You may allow 5-10kg infants to breathe spontaneously for short cases but use assisted ventilation for the longer cases. Allow spontaneous respiration for children over 10kg. If only the Oxford inflating bellows is in use then you must remember that its total volume is 2 litres: only slight movement is needed to ventilate babies. You may prefer to insert a paediatric self-inflating bag instead. As ether has now been removed from the WHO essential drugs list halothane will be the main volatile in use in remote locations. With halothane it is much safer if oxygen can be added to air using reservoir tubing at least 1 metre in length.

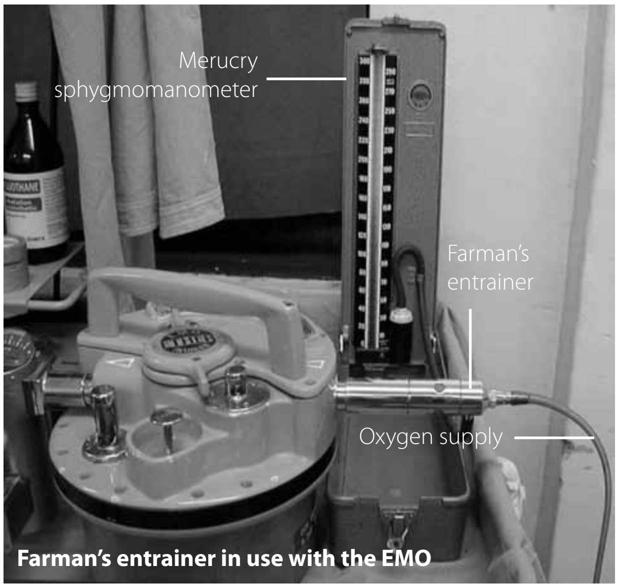

Figure 5. *Farman's entrainer in use with the EMO.*

Even though it is challenging anaesthetising small babies with minimal equipment, the drawover system can provide a safe, robust, portable and cost effective system for anaesthetising babies and children.

Key points:

- <5kg assist ventilation for all cases
- 5-10kg spontaneous ventilation for short cases, assisted ventilation if longer than 20 minutes
- >10kg spontaneous ventilation unless muscle relaxation required.

REFERENCES

1. Primary Anaesthesia Edited by Maurice King.
2. Anaesthetic vapour concentrations in the EMO system. H.G. Schaefer & J.V. Farman. *Anaesthesia* 1984; **39**: 171-80.
3. Minimum oxygen requirements during anaesthesia with the Triservice apparatus. A study of drawover anaesthesia a in the young adult. S.Q.M. Tighe, et al. *Anaesthesia* 1991; **46**: 52-6.
4. The Oxford miniature vaporizer in paediatric anaesthesia. An experimental study. I.H. Wilson et al. *Anaesthesia* 1988; **43**: 700-2.

Figure 1 and 6 courtesy of Dr Iain Wilson.