Anaesthetic equipment in low and low-middle income countries

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Learning objectives

After reading this article, you should be able to:

- list the components of a draw-over breathing system
- describe how draw-over systems and oxygen concentrators function
- discuss the challenges of using and maintaining anaesthetic equipment in LMICs

Abstract

There is a discrepancy between healthcare need and the ability to provide safe anaesthesia in low/low-middle income countries (LMICs). There is a shortage of medically trained anaesthetists. Most anaesthetics are provided by non-physician anaesthetists who may not have studied the core sciences underpinning anaesthesia, but are clinically very competent. Poor infrastructure is common, such as a shortage of piped medical gases and critical care beds. Safe anaesthesia depends on effective technology, and on consumables such as cannulae, and drugs, all of which are under-provided resources in LMICs. Much of the equipment used in the developed world is unsuitable for use in LMICs. Anaesthetic equipment used in LMICs, such as draw-over breathing systems and oxygen concentrators, may be unfamiliar to developed world anaesthetists. Cleaning and maintenance of equipment is usually the responsibility of the anaesthetist, who needs a good understanding of how it works.

Keywords Delivery of healthcare; durable medical equipment; equipment and supplies; hospital

Royal College of Anaesthetists CPD Matrix: 1A03; 1I02

Patients requiring anaesthetic intervention in low/low-middle income countries (LMICs) are different from those in the developed world. They are often younger, with fewer age-associated comorbidities (e.g. type 2 diabetes mellitus, COPD, ischaemic heart disease), and due to societal attitudes and poor transport infrastructure they may present to hospital later and sicker. The common operations performed differ also — most are obstetric cases or polytrauma, with the emphasis mostly focused on emergency rather than elective surgery. These circumstances present challenges to the anaesthetist, who is also faced with limited resources.

A 2007 survey of anaesthesia provision in Uganda identified a shortage of resources required to deliver safe anaesthesia. *Only* 23% of respondents stated they could deliver safe anaesthesia to adults, 13% to children, and only 6% had the facilities for a safe caesarean section.[1] Anaesthetic equipment in LMICs needs to be able to withstand extreme temperatures, humidity, be physically robust, easy to use and service locally, with readily available cheap spare parts. Compressed gas supplies and electricity are often in short supply; equipment needs to be able to function without either. The World Federation of Societies of Anaesthesiologists (WFSA), in collaboration with the World Health Organization, published updated guidelines in 2018 detailing an international standard for the provision of safe anaesthesia in LMICs.[2]

Draw-over systems and vaporizers

Plenum vaporizers rely on compressed gas supplies to function, but these are a scarce resource in LMICs. Economical use of compressed gases would require a circle system, oxygen analyser and supply of sensors, agent analyser, soda lime, as well as an anaesthetist trained in the technique. Draw-over has many advantages, including the ability to work with an inexhaustible supply of atmospheric oxygen in the absence of compressed gas or electricity.

A draw-over system consists of a low resistance breathing circuit, a draw-over low resistance vaporizer, valves, and self-inflating bag or bellows (Figure 1). Atmospheric air provides the main source of oxygen. There is no requirement for agent monitoring as it is a one-way breathing system. The carrier gas is drawn through the system by the patient's respiratory efforts or by the bellows. Flowmeters are not required as the required flow is automatically delivered. The inspired concentration of oxygen can be increased using a reservoir which fills with oxygen during expiration. A low flow of supplementary oxygen can make a significant difference to the final inspired concentration, for example an additional oxygen supply of 2 litres/min increases the inspired concentration of oxygen to approximately 52% when min volume is 5 litres/min.

Draw-over vaporizers, e.g. Oxford miniature vaporizer (OMV) and Epstein, Macintosh, Oxford (EMO) vaporizer, are in-line with the breathing circuit, have a *low* internal resistance, and a degree of thermal compensation. Most have standard 22-mm connections, a control dial to set the desired anaesthetic vapour concentration, and often have an arrow on the top or side to indicate direction of flow. Incoming gas is split into two streams. One stream passes into the vaporizing chamber where it is saturated with vapour, and the second stream bypasses this. The two streams are mixed to deliver the pre-set concentration of anaesthetic vapour (Figure 2). There is no requirement for anaesthetic agent monitoring as the output concentration from the vaporizer is delivered to the patient by a one-way system, with no rebreathing.

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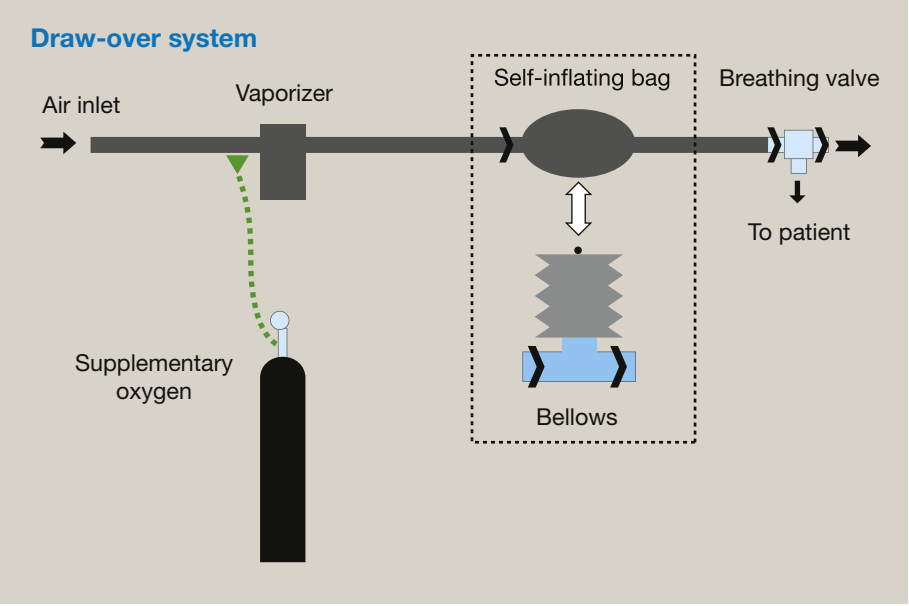

Figure 1

Some draw-over vaporizers can be used for more than one anaesthetic agent — for example, isoflurane and halothane have identical saturated vapour pressures. A draw-over vaporizer calibrated for isoflurane will therefore also be accurate for halothane, i.e. setting the control to deliver 1% will deliver 1% halothane or isoflurane. If using a volatile agent other than that for which the vaporizer is made, label the vaporizer clearly with the contents, and empty it at the end of the case or list. Isoflurane and halothane are not equipotent, halothane has a lower MAC. Check the level of agent in the vaporizer regularly to avoid it running dry. Unlike plenum vaporizers, draw-over vaporizers cannot be filled while in use without first being turned off as air would be drawn in to the vaporization chamber, increasing the final concentration of anaesthetic agent delivered to the patient. The amount of anaesthetic delivered to the patient depends on both the inspired concentration and the minute ventilation, so an increase in either or both will deepen anaesthesia (an important difference from a conventional circle system).

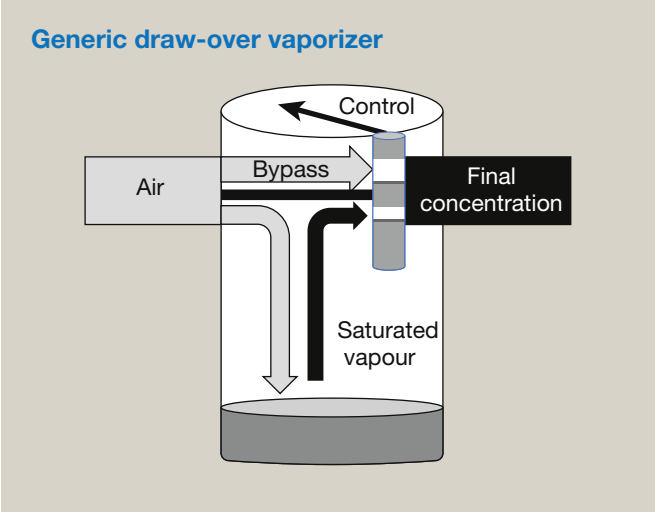

Figure 2

The OMV is the most common draw-over vaporizer in use (Figure 3). It is small, with a liquid capacity of 20 or 50 ml, and therefore runs the greatest risk of running dry; however, regular refilling helps maintain temperature. It is easy to knock over when in use, causing anaesthetic agent to enter the bypass stream leading to dangerously high concentrations of vapour being delivered to the patient. Should it tip over, disconnect immediately from the patient before sorting out the spill. Regular emptying of the vaporizer and discarding the contents is an important part of maintenance, especially if halothane is used. Halothane contains 0.01% w/w thymol, which is inert but sticky and can cause the moving parts of the vaporizer to stick.

Draw-over circuits have drawbacks for paediatric use, especially in children weighing <20 kg. They do not work efficiently at small tidal volumes, where lower inspiratory flow rates can lead to lower concentrations of anaesthetic agent than those set by the control being delivered. Inhalational induction is also more challenging as room air entrained through a leak around the facemask dilutes the anaesthetic vapour concentration. Common alternatives are the use of ketamine, or the use of a high flow of oxygen (8–10 l/min) through the vaporizer to drive a conventional Ayre's T-piece.

Unfamiliarity with draw-over equipment can lead to incorrect assembly of the system and patient harm. The AAGBI Draw-Over Working Party have developed a checklist that can be used to check draw-over equipment, and improve patient safety.[3]

Oxygen concentrators

Safe anaesthesia requires a reliable oxygen supply. Twenty-two per cent of respondents in the Uganda survey were without an oxygen source.[1] In the developed world the main sources of medical oxygen are oxygen cylinders or vacuum-insulated evaporators (VIEs). In LMICs, hospitals must purchase and

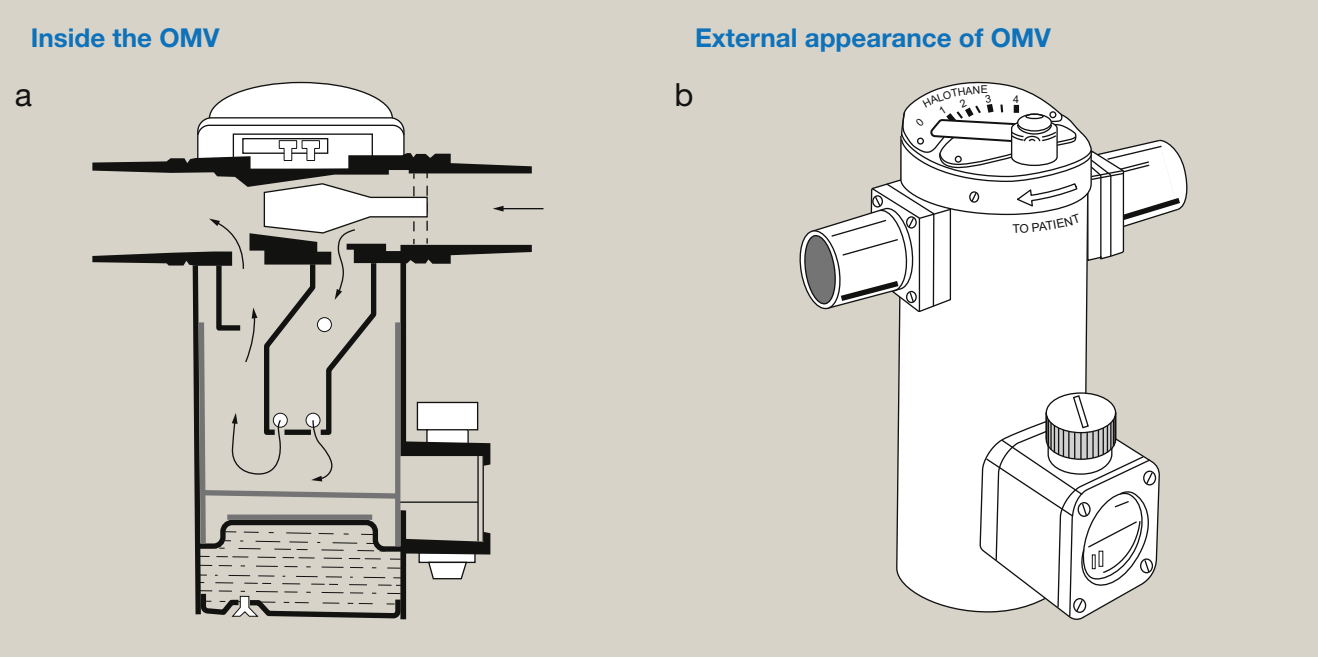

Figure 3

maintain their own oxygen cylinders, as well as pay for transport for filling (which can be impossible to do with bad roads or in wet seasons). The cost of cylinder oxygen is ten times higher in LMICs than in developed world countries. Non-UK standard oxygen cylinders are common, an oxygen cylinder may contain a different gas, or oxygen may be stored in a cylinder usually used for another gas. Oxygen can be wasted through leaks at the manifold, poorly maintained hospital pipelines, leaks from tubing, and the use of industrial pressure regulators set at pressures up to 7 bar. This results in reduced delivery of oxygen to the patient and drives up costs for the hospital.

Oxygen concentrators can provide oxygen for anaesthesia (Figure 4). They have helped reduce dependence on cylinder supplies, but rely on mains electricity so back up of oxygen or electricity is needed. Oxygen concentrators produce oxygen at a concentration of 95% by passing atmospheric air through dust filters and then zeolite. The active component of zeolite is aluminium silicate which has a high surface area for adsorption of nitrogen and water vapour, leaving oxygen and argon in the product gas. The physical process of adsorption can be reversed by a regeneration cycle. However, if the flow demanded exceeds the adsorption capacity (i.e. the maximum stated flow for the machine), some air will get through, diluting the delivered oxygen. Small concentrators can deliver flows of up to 10 l/min, with a flow limiter to prevent excessive flows. Most will shut down if the delivered oxygen concentration falls below 70%.

Not all oxygen concentrators are created equal; some have been shown to stop working when environments with temperature and relative humidity or mains voltage like that seen in African countries has been recreated.[4]

The most common cause of failure of an oxygen concentrator is clogging of the inlet filter with dust. This is easily remedied by washing the filter under the tap. Zeolite adsorbs water vapour and will continue to do so when left unused. Once fully saturated it cannot be regenerated, so run the concentrator for at least an hour a week to keep it in good condition. Small concentrators which produce an outlet pressure of only 1.3 bar cannot be used with compressed gas machines which require 4 bar pressures.

Monitoring

Pulse oximetry is essential for the delivery of safe anaesthesia. The 2007 Ugandan survey showed 74% of anaesthetists were then working without a pulse oximeter.[1] A precordial stethoscope, providing reliable information about ventilation and circulation, may be the only equipment available for monitoring. The WFSA recommends the inclusion of pulse oximetry, and with Lifebox and the AAGBI is working to ensure access to a pulse oximeter in areas where they are lacking. The Lifebox oximeter is robust, uses rechargeable batteries, and does not need recalibration.[5]

Non-invasive blood pressure monitoring is essential, using a sphygmomanometer or an automated device. The most common cause of failure is the lack of access to replaceable parts. There is a low prevalence of ischaemic heart disease in patients undergoing surgery in LMICs, and ECG monitoring is less essential.

Oxygen analysers are essential if there is any possibility of delivering a hypoxic mixture to the patient (e.g. when nitrous oxide is being used) and are useful for checking an oxygen concentrator. Fuel cells are plentiful and cheap, however, often do not last as they degrade over time, especially if left in a high FiO_2 environment. Correct use and interpretation of capnography requires training of staff and calibration of equipment, neither of which may be readily available in LMICs. Capnographs are much more expensive to purchase relative to, for example, fuel cells, further limiting their practicality in LMICs.

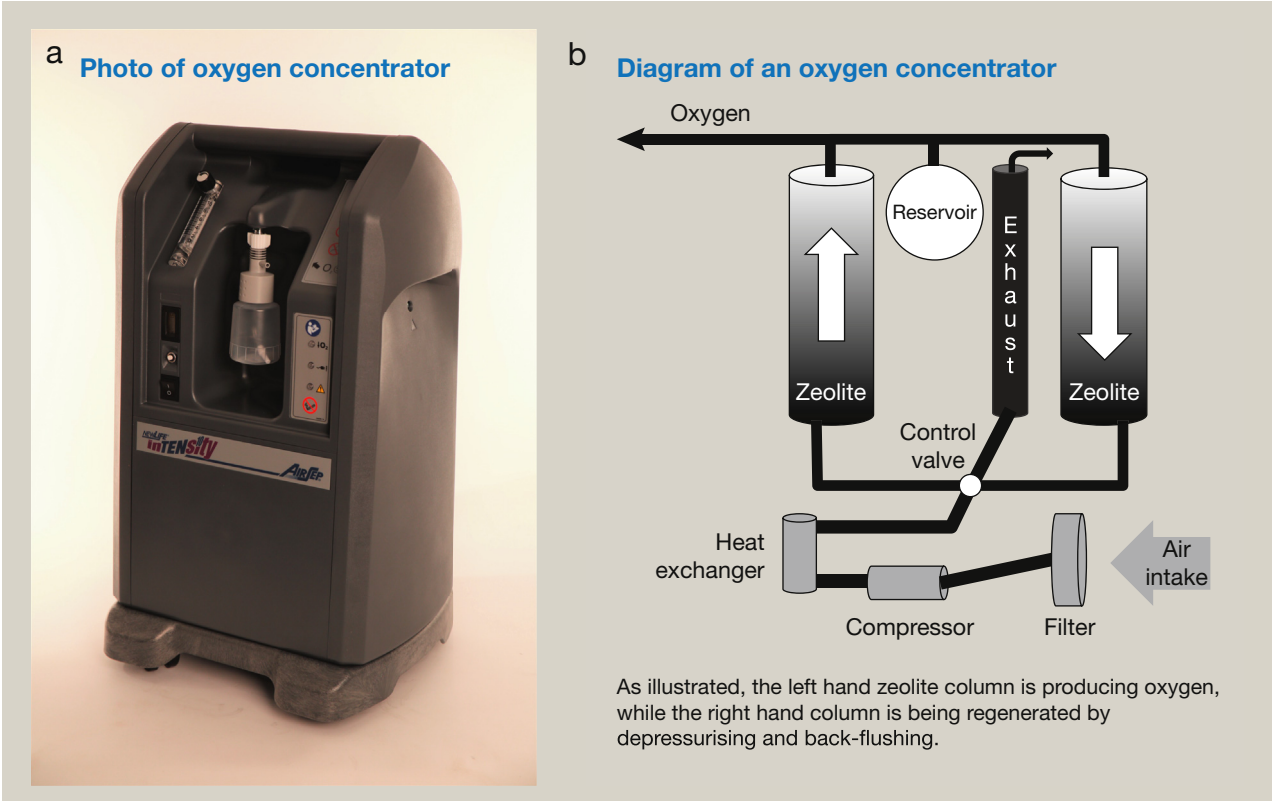

Figure 4

Other anaesthetic equipment

Equipment supplies (e.g. tracheal tubes, spinal needles, cannulae, and gloves) are often insufficient and unreliable. Many 'single-use' items are re-used repeatedly, sometimes without satisfactory disinfection. Comments from anaesthetists who participated in the Ugandan survey include:

> "I rarely intubate due to the lack of airway equipment and the irregular supply of oxygen."[1]

> "We usually send the family to buy cannulae from pharmacies in town … We recycle the tracheal tubes."[1]

> "… there are no spinal needles. The district cannot afford to buy such needles."[1]

Equipment maintenance

Facilities and trained personnel to maintain equipment may not exist. Equipment is sometimes transferred from a smaller hospital to a larger one for repair, adding to cost, and there is no substitution while equipment is being repaired. Simple, regular maintenance, keeping things clean, and keeping good records can avoid crises. When ordering new equipment, first ask about spare parts and user and technician training. Anaesthetic equipment is often donated from developed countries, e.g. USA. Any North American electrical equipment will be designed to function at a different voltage, frequency, and with a different plug type than that used in most LMICs. This can result in a reduced lifespan of equipment without the means to alter or repair it. ◆

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FURTHER READING

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