Anaesthesia for Difficult Environments

a report by
Diamedica Ltd

The various improvements in the design and performance of anaesthetic machines in recent years have undoubtedly led to significant increased patient safety. However, as these machines have become more sophisticated so their cost has escalated, along with their technical and servicing complexity. A new state-of-the-art anaesthetic machine in the UK currently costs from £30,000 to £40,000, a figure clearly beyond the range of most anaesthetic departments in less affluent parts of the world.

These new machines function well when used in sophisticated environments, where maintenance and servicing facilities can be guaranteed and piped gases are available. However, they rely heavily on computer technology and frequently require a degree of attention often beyond the skills of even the most competent local hospital technicians. Even a minor fault can be disastrous if no-one knows how to correct it. Consequently, a service contract is essential, adding a further 10% on the purchase price per year.

Moreover, they are not designed for use in adverse environments or when the supply of electricity or oxygen may be interrupted without warning, rendering them unworkable with catastrophic results.

Attempts to introduce these expensive modern anaesthetic machines into difficult environments have repeatedly ended in failure and have proved to be an expensive waste of resources.

Essential Requirements of a Universal Anaesthesia System

Safety

The system must continue to operate without interruption even if the supplies of oxygen or electricity fail, a situation that has been responsible for many avoidable tragedies and is not uncommon in remote locations. It should not be reliant on supplies of piped gases, which may be unavailable or prohibitively expensive in some parts of the world.

Additionally, the system should not require nitrous oxide, thus preventing accidental delivery of a hypoxic mixture with potentially fatal consequences for the patient.

Economy

An anaesthesia system must be affordable if it is to be used worldwide. Firstly, the purchase price must be significantly lower than for conventional continuous flow machines and secondly, its maintenance requirements must be minimal. The system must be robust, with servicing undertaken by locally trained technicians. Expensive annual servicing contracts should not be necessary.

Most important of all, the running costs should be very low. With conventional continuous flow systems costing around £4.50 per hour to run (US$8.19 at US$1.82/£1), this is a very significant additional cost for hospitals operating on a tight budget. An anaesthesia system with running costs at less than one-third of this rate would be highly desirable.

Simplicity

An anaesthesia system should be simple to operate, with first-time users able to master it quickly and easily.

Versatility

The system should be suitable for use on both adults and children. It should also be dual purpose as an anaesthesia system in an operating theatre and as a ventilator in a post-operative recovery room or intensive care unit.

The Ideal Solution

An anaesthesia system that meets all these essential requirements already exists. Specifically designed to overcome the difficulties frequently encountered by those practising under adverse conditions, it is now being used successfully in 12 countries across Europe, Asia and Africa.

The Glostavent™ incorporates three components, each of which has (in its own right) already proved valuable to anaesthetists practising in difficult working

Figure 1: Glostavent™ with its Inventor, Dr Roger Eltringham

conditions. These components take the form of the draw-over anaesthesia system, the Manley Multivent ventilator and the oxygen concentrator.

1. The Draw-over Anaesthesia System

In this system, atmospheric air is used as the carrier gas, which is drawn over a low resistance vapouriser by the patient's own inspiratory efforts. It therefore does not depend on the supply of pressurised gases or cylinders, which are expensive and may even be unavailable.

2. The Ventilator

The ventilator is a mechanical version of the Oxford Inflating Bellows, powered by either oxygen or air at a pressure of 140kPa. Therefore, it is independent of the electricity supply and is very easy to operate having just two controls – tidal volume and respiratory rate. Unlike other ventilators it is extremely economical in the consumption of driving gas, requiring just 10% of the minute volume delivered to the patient. When oxygen is being used as the driving gas, further savings are achieved as (having powered the bellows) the oxygen is collected and returned to the patient circuit, supplementing the inspired oxygen concentration. In other words, the same oxygen can be used twice – firstly to drive the ventilator and secondly for the patient to breathe.

3. The Oxygen Concentrator

This electrically driven device provides an unlimited supply of oxygen from the atmosphere, without the expense of purchasing or transporting heavy oxygen cylinders.

Atmospheric air containing 20% oxygen is drawn into the concentrator and compressed to 140kPa. The nitrogen is then absorbed by canisters containing zeolite, leaving residual oxygen for the patient. It can produce a concentration of 90% oxygen at a flow rate of up to five litres per minute, costing only £0.025p (US$0.046) per hour.

The oxygen concentrator used in the Glostavent has been specially modified to enable some of the compressed air generated to be diverted in order to drive the ventilator. In this way, a separate compressor is not required and a continuous supply of compressed air is available at no extra charge.

This integrated system is mounted on a workstation with two oxygen cylinders kept in reserve for electricity failures (which prevents the oxygen concentrator from functioning).

Under normal circumstances, when electricity is available, it is more economical to use the oxygen concentrator both as source of oxygen for the patient's breathing and of compressed air to drive the ventilator. Should the electricity fail, the reserve oxygen cylinders are used; one as a source of oxygen for the patient, the other as a source of pressure to drive the ventilator. In this way, the anaesthetic can be continued without interruption.

When the reserve oxygen cylinders are being used, conservation becomes important and oxygen should not be wasted.

Using the standard type of gas driven ventilator, a minute volume set for the patient of six litres would utilise six litres per minute of driving gas. Consequently a 600 litre cylinder would only last for 100 minutes. In contrast, because of the low requirement of driving gas for the ventilator, the same size of cylinder would last 10 times as long (16 hours). Moreover, the recycling of this driving gas means that F_iO_2 of 35% to 40% will be achieved at all times, without the need for supplements from the oxygen cylinder.

Further Developments

A temperature compensated vapouriser is currently being developed in order to enhance accuracy. This new type of vapouriser is predicted to be a considerable improvement on the bimetallic strip used in conventional vapourisers.

Practical Experience

The anaesthetic records of 953 patients (ASA I & II), who had received anaesthesia delivered by the Glostavent for elective surgery were analysed. Each patient received a standard technique, consisting of an intravenous induction, followed by either halothane or isoflurane. This was administered from an Oxford Miniature vapouriser in a concentration of 1.5MAC (Mean Alveolar Concentration), delivered in an air/oxygen mixture supplemented by fentanyl (0.3mcg per 15 minutes). Relaxants were used when clinically indicated.

The patients were monitored throughout the course of anaesthesia, using the full range of equipment recommended by the Association of Anaesthetists of Great Britain and Ireland. Draw-over anaesthesia was used in each of the 878 adult patients, whereas continuous flow anaesthesia was used in 75 paediatric patients (<25kg). Both controlled and spontaneous respiration was used, with the oxygen supplied either by the concentrator or from the oxygen cylinder.

The Glostavent functioned faultlessly in each case, regardless of whether the driving gas used was compressed air from the concentrator or oxygen from the cylinder.

Conclusion

The Glostavent was shown to be reliable, predictable, economical and versatile. Using the technique described, with halothane as the volatile agent and the oxygen concentrator as the source of both oxygen and compressed air, it is possible to reduce the cost of maintaining anaesthesia to under £1.50 per hour (US$2.73). This represents a saving of approximately £3.00 per hour (US$5.46) over a comparable technique using cylinders and a conventional anaesthetic machine. In any anaesthetic room with moderately heavy use, the Glostavent would easily pay for itself within one to two years.

Figure 2: Dr Felix Mboya, Consultant Anaesthetist at Queen Elizabeth Central Hospital, Blantyre, Malawi, with his New Glostavent