

The Diamedica portable anaesthetic machine: a comparison with the Triservice Apparatus

In disaster and military situations inhalational anaesthesia should be delivered using an anaesthetic machine that has been specifically designed for the environment. It should be portable, intuitive to operate, contain few parts that could malfunction and require minimal maintenance. It should be suitable for use with any size of patient using controlled or spontaneous respiration. It should be able to deliver sufficient concentration of volatile agent to facilitate inhalational induction. Given the extensive range of environments in which it may be used, its performance should be predictable over a wide range of temperatures. It should not be reliant on the availability of any single anaesthetic agent, electricity or oxygen. It should be efficient in its use of volatile agent and oxygen. The Diamedica Portable Anaesthetic Machine (DPA 02) fulfils these criteria. It is smaller, lighter, less expensive, more versatile and more economical than the Triservice Apparatus and is recommended as a worthy successor for use in difficult environments in any part of the world.

Following natural disasters and during military conflicts, emergency anaesthesia may be required in inaccessible locations under field conditions where there are no local facilities. In such situations, everything required by the anaesthetist, including the anaesthetic machine, has to be carried into position.

To be suitable for use in these circumstances an anaesthetic machine must not only be easily portable but also able to function in the absence of a supply of oxygen or electricity or even both simultaneously. The Triservice Apparatus (Penlon Ltd, Abingdon, UK) is an example of such an anaesthetic machine that has been used by the armed forces for over 40 years with great success.¹

In recent years there have been many advances in equipment for inhalational anaesthesia in difficult circumstances.^{2,3} The Diamedica Portable Anaesthetic Machine (DPA 02) has been developed to incorporate many of these advances into a single unit that can improve the safety of patients undergoing anaesthesia in field conditions.

A comparison is made between the Triservice Apparatus and the DPA 02.

THE TRISERVICE APPARATUS

The Triservice Apparatus (Figure 1), which incorporates a draw-over breathing system, has filled the role of a portable anaesthesia delivery system for many years and has proved its worth in various fields of conflict and remote locations.^{4,5} It has the following components:

A) Reservoir. This consists of a length (60 cm) of corrugated tubing with an open end for the intake of air and with a side arm for the administration of supplementary oxygen.

B) Vaporiser. The Triservice Apparatus has two Oxford Miniature Vaporisers (OMVs) used in tandem. Both have interchangeable scales for use with halothane, isoflurane or trichloroethylene. Each holds 50 ml of anaesthetic agent. The vaporisers have retractable flaps at the base to reduce the likelihood of overturning during use.

C) Inspiratory tubing and self-inflating bag. A variable length of corrugated tubing with an in-line self-inflating bag and unidirectional valve connects the vaporisers to the patient.

D) Non-rebreathing valve. A non-rebreathing valve is situated as close as possible to the patient's airway. This is an essential component of the draw-over system, the function of which is to ensure that inspiration is solely from the anaesthetic machine and that expiration is solely to the atmosphere. This is normally a Laerdal valve although other makes such as Ambu can also be used.

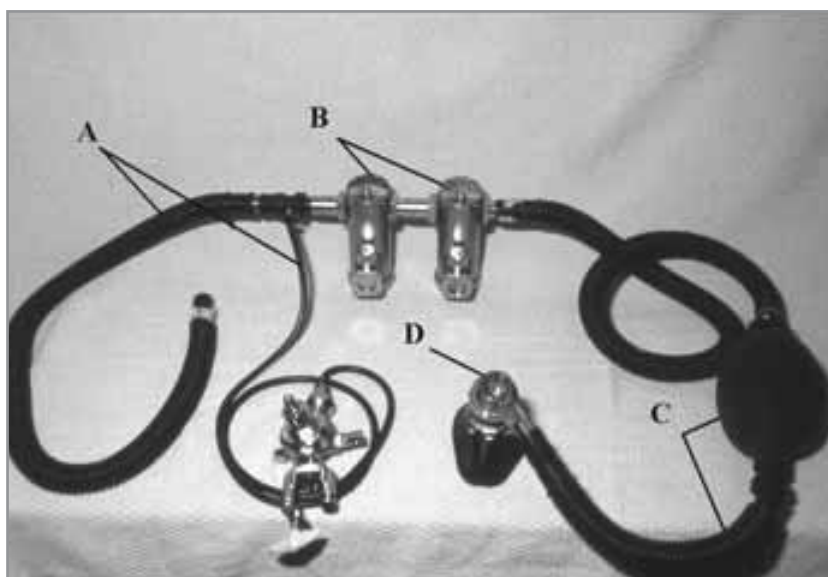
E) Expiratory tubing. A length of corrugated tubing connected to the expiratory limb of the non-rebreathing valve can be added for scavenging of expired gases (not shown in Figure 1).

The Triservice Apparatus may be used to administer halothane, isoflurane or trichloroethylene with spontaneous or manually controlled ventilation with or without oxygen supplementation. It is normally used in draw-over mode but can be used in continuous flow mode provided that the open end of the oxygen reservoir is occluded.

The Triservice Apparatus is supplied in an aluminium alloy box measuring 60 cm x 41 cm x 25 cm and weighing 25 kg in total.

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Figure 1. The Triservice Apparatus.



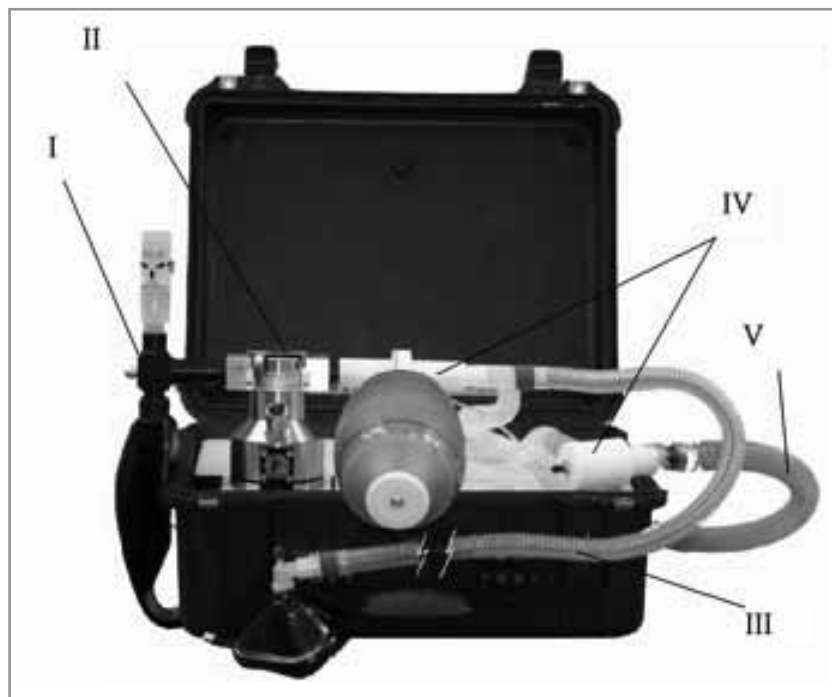


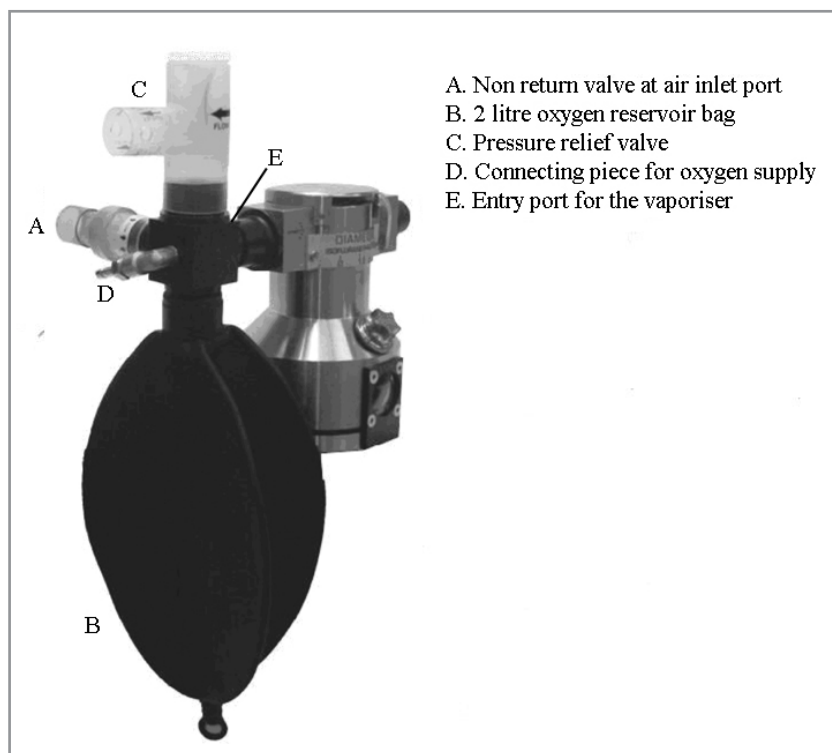
Figure 2. The Diamedica Portable Anaesthetic Machine (DPA 02).

THE DIAMEDICA PORTABLE ANAESTHETIC MACHINE (DPA 02)

The Diamedica Portable Anaesthetic Machine (DPA 02, Diamedica Ltd, Barnstaple, UK)⁶ is an updated version of the original Portable Glostavent (DPA 01) whose successful deployment in Rwanda and Uganda has been previously reported.⁷ It contains a similar draw-over breathing system but with important changes to the non-rebreathing valve and the respiratory tubing.

It is supplied in a polymer container the size of a small suitcase measuring 42 cm x 50 cm x 20 cm and weighing less than 10 kg. The hermetically sealed container is manu-

Figure 3. The reservoir unit and surrounding connections.



- A. Non return valve at air inlet port
- B. 2 litre oxygen reservoir bag
- C. Pressure relief valve
- D. Connecting piece for oxygen supply
- E. Entry port for the vaporiser

factured to a military standard (Defstan 81/41) and is shock proof, waterproof, dust proof and corrosion proof (Figure 2). It includes a pressure relief valve, which is required for air transport.

The DPA 02 contains the same five basic components as the Triservice Apparatus but each has been modified as follows:

I) Reservoir. The open-ended reservoir tube used in the Triservice is replaced by a dedicated reservoir unit (Figure 3). This unit has a valve at the air inlet to prevent spillage of oxygen (A), a 2 litre reservoir bag to increase the volume of the reservoir (B) and a pressure relief valve set at 7.5 cm water to prevent over distension of the reservoir bag (C), a connecting piece for the oxygen supply (D) and a port to connect with the vaporiser (E).

The modifications to the reservoir unit enable conversion to continuous flow mode to be made by simply increasing the flow rate of supplementary oxygen. When the flow of oxygen exceeds the patient's minute volume, the reservoir bag distends, the pressure rises causing the non-return valve to close and the flow to the patient becomes continuous. If, however, the oxygen flow rate is less than the patient's minute volume, the pressure in the reservoir falls below atmospheric pressure, room air enters the reservoir through the non-return valve and the system operates in draw-over mode. The change of mode occurs automatically and requires no further intervention by the anaesthetist.

These modifications to the reservoir confer further advantages. Firstly, wastage of oxygen can be completely eliminated. This is achieved by titrating the oxygen flow rate to ensure that the reservoir bag does not become distended and allow escape of oxygen through the pressure relief valve.

Secondly, the inspired oxygen concentration can be maximised during periods of hyperventilation, for instance during pre-oxygenation, by ensuring sufficient flow to prevent the reservoir bag from collapsing, allowing dilution with atmospheric air. Thirdly, the reservoir unit takes up less space within the container.

II) Vaporiser. The two OMVs used in the Triservice Apparatus are replaced by a single Diamedica draw-over vaporiser (Figure 4) calibrated for use with halothane or isoflurane.⁸ It can be used for both draw-over and continuous flow anaesthesia. It has a larger reservoir than the OMV (150 ml compared to 50 ml), greater consistency of output and is accurate over a wider range of temperatures. The scale is calibrated to produce a higher concentration of halothane and isoflurane (5%) enabling gaseous induction to be more readily achieved. (A separate vaporiser calibrated for sevoflurane is also available.) The Diamedica vaporiser has a low centre of gravity and is completely stable when screwed into position at the base of the container, so the danger of overturning and allowing liquid anaesthetic agent to enter the circuit is eliminated.

III) Inspiratory tubing and self-inflating bag. The 2 litre self-inflating bag is sited immediately beside the vaporiser and attached to the base of the container to provide stability. The self-inflating bag is at right angles to the direction of flow. A smaller self-inflating bag is supplied for use in paediatric patients. The lengths of respiratory tubing for both inspiration and expiration are combined as a single lightweight double lumen tube, with the two halves separated by a septum running down the middle of the tubing. (Limb-O circle breathing unit, Vital Signs Ltd, Littlehampton, W. Sussex, UK).



IV) Non-rebreathing valve. The Laerdal valve, situated at the patient's airway in the Triservice Apparatus, is replaced by the Diamedica valve.⁹ This valve consists of two interconnected parts, located at the base of the container and attached, respectively, to the inspiratory and expiratory halves of the double lumen tube.

V) Expiratory tubing. The expiratory side of the double lumen respiratory tubing leads to the scavenging tubing via the expiratory part of the Diamedica valve.

A regulator/flow meter with a pin index or bull nose connection is supplied for attachment to an oxygen cylinder. This has advantages over a vertical flow meter in that it is accurate in any position and is easier to read. The oxygen flow rate can be set from 0.5 to 15 litres min^{-1} to enable the breathing system to be rapidly flushed with oxygen in an emergency. A connecting tube is supplied to link the cylinder with the reservoir.

Included in the container is a Lifebox pulse oximeter and finger probe as recommended by the Association of Anaesthetists of Great Britain and Ireland (AAGBI) as part of the World Federation of Societies of Anaesthesiologists' (WFSA) Global Oximetry Project.

DISCUSSION

Despite all the advances in the design and performance of modern sophisticated anaesthetic machines that have occurred in recent years, they remain totally dependent on adequate support facilities. Consequently, the need for a simple portable anaesthetic machine that can be used in isolated situations where there are no support facilities remains as great as ever.

The DPA 02, in common with the Triservice Apparatus, is well suited to this scenario since it does not require a source of electricity or compressed gas in order to function. It may be used with cylinder oxygen, an oxygen concentrator or if neither is available, with atmospheric air.

The DPA 02 is designed to facilitate the conservation of oxygen. This is particularly important in remote locations where the supply of cylinders may be precarious or non-existent for prolonged periods. The design of the modified reservoir has made it possible for wastage of oxygen to be totally eliminated and thus reduce the flow rate required to provide a given inspired oxygen concentration. For example, a patient with a minute volume of 5 litres will have a FiO_2 of approximately 36% when there is a flow of supplementary oxygen of just 1 litre min^{-1} .¹⁰ At this rate of utilisation, a single E size oxygen cylinder containing 680 litres would be expected to last for more than 11 hours.

When anaesthetising children, still further economy is possible if the draw-over breathing system is used in preference to the Mapleson F system, in which a fresh gas flow of 2–3 times the patient's minute volume is recommended.

Furthermore, this reduction of volume of oxygen used is accompanied by a corresponding reduction in the amount of volatile agent vaporised. The draw-over system has been shown to be satisfactory in children down to a weight of 10 kg ¹¹ but, if the Mapleson F system is preferred, conversion to continuous flow can be readily instituted when using the DPA 02 as described above.

When using the Triservice Apparatus, the non-rebreathing valve is positioned as closely as possible to the patient in order to reduce dead space and the incidence of rebreathing. This additional bulk in the region of the patient is very inconvenient as it may lead to obstruction of the airway or



Figure 4. The Diamedica vaporiser (DDV).

kinking of the tracheal tube. The situation is compounded if there is also a scavenging tube attached to the expiratory port of the valve. With the introduction of the Diamedica valve, which is situated away from the patient, combined with the new lightweight double lumen respiratory tubing, these problems are completely eliminated.

The ability of the Diamedica draw-over vaporiser to deliver higher concentrations of halothane and isoflurane than the OMV enables gaseous induction to be more readily achieved. The version calibrated for sevoflurane can deliver a concentration of 8%, thus further facilitating gaseous induction when other methods are unavailable.

In situations where sophisticated electronic monitors are absent or cannot be calibrated accurately, the simplicity of the draw-over design is an important factor in patient safety. It is, for example, impossible to deliver a hypoxic mixture inadvertently when atmospheric air is the carrier gas to which oxygen is then added. Similarly, carbon dioxide levels depend solely on respiratory excursion rather than the condition of soda lime or the adequacy of fresh gas flows, as in other systems. Furthermore, the concentration of volatile agent reaching the patient is the same as that dialled at the vaporiser and is not affected by dilution with unknown expired concentrations as when a circle system is in use.

For these reasons, a conscientious anaesthetist using continuous clinical monitoring is likely to be at least as safe when using a draw-over system as an anaesthetist using the latest sophisticated apparatus and relying on monitors that cannot be serviced or calibrated regularly.

CONCLUSION

In disaster and military situations inhalational anaesthesia should be delivered using an anaesthetic machine that has been specifically designed for the environment. It should be portable, intuitive to operate, contain few parts that could malfunction and require minimal maintenance. It should be suitable for use with any size of patient using controlled or spontaneous respiration. It should be able to deliver sufficient concentration of volatile agent to facilitate inhalational induction. Given the extensive range of environments in which it may be used, its performance should be predictable over a wide range of temperatures. It should not be reliant on the availability of any single anaesthetic agent,



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Conflict of interests

Mr R Neighbour is an employee of Diamedica Ltd.

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