

Safety features in modern anaesthetic machines: an update

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Editorial

Anaesthesia machines have come a long way since the ancient Boyles apparatus. The main focus of research in these machines has been to improve the safety features, in order to prevent delivery of hypoxic gas mixtures and alert the anaesthesia care provider of any other problems. Modern anaesthesia machines have several safety features, for patient as well as user safety, some of which are less well-known. This editorial gives a brief overview on these safety features, which may prove very helpful, especially in emergency circumstances.

The modern anaesthesia machines have five basic subsystems:

- I. Gas supply: pipeline; cylinders
- II. Controlled flow of gases and vapours: Flowmeters; Vaporizers
- III. Gas delivery: breathing system and ventilator
- IV. Waste gas scavenging
- V. Monitoring

These are classified into the pneumatic, electronic and scavenging components. When we equate it to the history of anaesthesia, the “pneumatic system” represents the “Old Stone Age”, the “electronic system” marks progress to the “New Stone Age” and the “scavenging system” has ushered in the “Iron Age”. With advancements in perioperative care, there is tremendous improvement in anaesthetic tools with the passage of time and hence, the list of safety features is also rapidly expanding. Chalking down of international safety specifications has resulted in standardization of features between different brands of workstations. The standard safety features in a modern anaesthetic machine have been summarized below (Figure 1).¹⁻⁴

Ultramodern anaesthetic machines have additional safety features and are programmed with a computerised safety self check feature which is initiated at start up. This should be repeated and checked before every case and ideally not be bypassed. Nevertheless, it can be bypassed only for a fixed number of times consecutively in case of an emergency. Pre-use check along with regular maintenance is the key to circumvent mishaps due to machine faults. The safety self-check list for Dräger Primus is depicted in Figure 2. Microprocessor controlled gas flow (electronically denoted by a digital display or ‘virtual flow meter tubes’) is featured in ultramodern units like *Dräger Fabius GS*; *Dräger Primus* and *Datex-Ohmeda S/5 Anaesthesia Delivery Unit*.⁵ Ventilators may either be double circuit, bellows type or single circuit, piston driven. The ascending bellows design is a safety feature since ascending bellows tend to collapse when disconnection occurs.⁶ The descending bellows continue their upwards and downwards excursion even after disconnection. The driving gas pushes the bellows upwards during the inspiratory phase while room air is entrained into the breathing system at the site of the disconnection

due to gravity, during expiratory phase. Hence conventional volume and pressure based disconnection monitors may fail to detect a disconnection.⁵ Safety feature in ultramodern descending bellows workstations (*Dräger Julian* and *Datascope Anestar*) is a carbon dioxide apnoea alarm which cannot be disabled while the ventilator is being used. Ultramodern piston ventilators use electricity as their driving force and do not require a driving gas. Fresh gas decoupling is a safety feature incorporated in both piston ventilators and descending bellows ventilators to prevent volutrauma. Piston ventilators include *Dräger Primus*, *Apollo*, *Narkomed 6000* and *Fabius GS*.⁵⁻⁷ Fresh gas decoupling eliminates interaction between fresh gas flow and tidal volume delivered to the patient eg., an anaesthetist can even press the oxygen flush button during ventilation without increasing the volume delivered to the patient. Inclusion of the reservoir bag in the circuit during mechanical ventilation is an additional safety feature. The visual movement of the reservoir bag is proof that the ventilator is functioning.

There are five practical clinical problems which are discussed below, along with their solutions:

- A. In event of power failure
 - a. There is a battery backup of at least 45 minutes with the pipeline gases switched off.
 - b. This extends upto 90 mins if the pipeline gas supply is switched on and power failure is limited to the work station power supply.
- B. In the eventuality of battery failure or battery exhaustion,
 - a. A safety oxygen valve capable of delivering 0-12 litres of oxygen via the closed circuit “Y” piece has been provided. It does not deliver gases through the open circuit. It operates on the manual ventilation mode. Volatile anaesthetic agents can also be simultaneously delivered based on their dial concentration. At this stage the Primus machine may seem to behave like a primitive Boyles machine with just the pneumatic component.

- C. Exhaustion of pipeline oxygen supply when the cylinders too are empty.
- The Drager Primus can function indefinitely for an unlimited period of time on just the ambient oxygen.
 - The piston driven ventilators do not require oxygen unlike the oxygen driven bellows of pneumatic ventilators.
 - All the modes of ventilation namely the Manual/spontaneous mode, volume mode, pressure mode and pressure support mode are compliant with this lesser known safety feature.
- D. Cylinder is accidentally left open.
- When the pipeline supply is on and the oxygen and nitrous oxide (N₂O) cylinders too are open, the machine preferentially utilizes the pipeline line oxygen and the oxygen in the cylinder is not consumed.
 - This is because the pipeline pressure is approximately 5psi higher than the cylinder pressure.
- E. Electronics in the machine failing to provide a gas flow to the common gas outlet (CGO).
- A stand-alone mechanical flow meter (separate from the back bar flowmeter) has been provided in workstations like Datex-Ohmeda Avance S5, which has to be consciously activated in the rare instance of electronics in the machine failing to provide a gas flow to the CGO. This flow usually may or may not pass through the vaporizers.

Conclusion

The more we say about safety the less it is. Further research in this field can add more safety features to our modern machines. To

conclude, for tackling the original problem “How to prevent the accidental delivery of a hypoxic gas mixture”, anaesthesiologists have several new tools in their armamentarium. Knowing the anaesthesia workstation and all its safety features is imperative to prevent a catastrophe.

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Conflicts of interest

The authors declare that there is no conflict of interest.

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