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Portable Ventilator for Emergency Patient

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ABSTRACT: A portable ventilator needs to be lightweight, sturdy, and capable of operating in challenging conditions with minimal upkeep. Typically, portable ventilators show the oxygen concentrations chosen by the operator but do not measure the actual delivery by the ventilator. Even if settings appear similar, portable ventilators might not offer identical support to the ICU machine in use. Therefore, it's crucial to allow a trial period before moving the patient. Portable ventilators assisting spontaneously breathing patients tend to be more intricate and usually require microprocessor control. For extended use outside the hospital, it's worth considering alternatives to oxygen cylinders like oxygen concentrators and liquid oxygen.

KEYWORDS: Oxygen Cylinder, ICU machine, ventilator.

I. INTRODUCTION

Mechanical ventilators utilized in intensive care units are advanced apparatuses engineered to ensure optimal lung ventilation. They integrate precise yet sizable pneumatic components designed for utilizing piped gases and mains electricity. However, these devices are generally unsuitable for patient transportation due to their bulkiness, weight, dependency on external power, and high gas consumption. Portable ventilators, on the other hand, are compact contraptions crafted to deliver mechanical ventilation in scenarios where piped gases and mains electricity are inaccessible. Thanks to modern engineering, these devices now boast a level of sophistication akin to traditional intensive care ventilators. Ideally, a portable ventilator, complete with oxygen and battery provisions, should be lightweight, durable, and capable of functioning in challenging environments with minimal upkeep. It should utilize available gas or electrical resources efficiently, be cost-effective, user-friendly, and offer a variety of effective ventilatory modes.

Portable ventilators serve various purposes, each with specific design requirements:

- (i) Primary Transfer: Typically from accident scenes.
- (ii) Secondary Transfer: Between healthcare facilities, whether within the same hospital or between different ones.
- (iii) Domiciliary Ventilation: Providing ventilatory support in a home setting.
- (iv) Improvised Intensive Care Facilities: Such as military field hospitals or civilian contingency plans.

These applications differ in patient conditions, operator expertise, and environmental demands. Consequently, a single device is unlikely to be optimal for all scenarios, leading to the availability of a range of ventilators. Throughout this review, three examples are considered (refer to Table 1). Key practical features include required gas and power supplies and supported ventilation modes.

Gas Supplies: Adequate oxygen is necessary to meet patient needs, and it may also facilitate a background gas flow through the breathing circuit (bias flow) or control the ventilator cycle.

During critical care transport, oxygen is commonly sourced from gas cylinders. Ambulances typically carry pairs of code F (1360 liters) or HX (2300 liters) cylinders in the cabin, along with smaller D (340 liters) or CD (460 liters) cylinders. Modern CD and HX cylinders have similar dimensions but are filled to 23,000 kPa instead of 13,700 kPa. They feature built-in four-bar pressure regulators and Schraeder outlets.

Ventilators with gas compressors, like the LTV-1000, can utilize various low-pressure oxygen sources to enrich ambient air. Oxygen concentrators may be used if cylinder supply is challenging, such as in military field hospitals. For aeromedical evacuation, low-pressure liquid oxygen systems can provide three times more gaseous oxygen than a cylinder of similar size.

The ability to regulate inspired oxygen concentration is vital for balancing the patient's oxygen needs, gas consumption, and mitigating the adverse effects of oxygen. A Venturi mechanism within the ventilator can draw ambient air into a



high-pressure oxygen source. For instance, the ventiPAC can provide inspired oxygen concentrations of either 100% or 45%, depending on whether the entrainment port is activated to mix air. The Oxylog 3000 adjusts the entrainment ratio through solenoid valves, offering a continuous range of oxygen concentrations.

In the absence of a high-pressure oxygen supply, the LTV-1000 takes a different approach. It measures oxygen supply pressure and utilizes a system of valves to blend oxygen proportionally with ambient air into a reservoir chamber for delivery to the patient. Notably, most portable ventilators display the inspired oxygen concentration selected by the operator rather than a measured value.

Table 1 Operating characteristics of three common portable ventilators

	Power for cycling	Power for inspiratory flow	Internal battery supply	External electrical supply	Gas supply (bar)	Bias flow (litres min ⁻¹)	Cycling requirement
VentiPAC 200D	Pneumatic	Pneumatic	~1 yr (alarm module only)	N/A	3–6	0	20 ml cycle ²¹
LTV-1000	Electric	Electric	1 h	Battery 3, 4, 9 h, 12 V DC,	2.8–5.5 or >0.7	10	0
Oxylog 3000	Electric	Pneumatic	3 h (NiMH) or 4 h (lithium)	240 V AC 10–32 V DC, 240 V AC	2.7–6.0	0.5	0

There are two main types of portable ventilators, each with its own mechanism of operation:

1. Portable Gas-Powered Ventilators:

These ventilators utilize pneumatic energy to drive inspiratory gas flow and regulate the respiratory cycle. The ventiPAC, for example, is a time-cycled flow generator powered by a high-pressure gas supply. It employs a mechanical oscillator to control the respiratory cycle, with an adjustable flow restrictor governing gas delivery during inspiration.

While effective, particularly for patients with severe respiratory distress, these ventilators may struggle to adequately support the patient's own breathing efforts. They incorporate a demand valve to provide fresh gas in response to inspiratory effort but do not reduce the work of breathing.

Monitoring ventilation adequacy through methods like end-tidal CO₂ monitoring and arterial blood gas sampling is essential, especially when using mixed air-oxygen settings.

2. Microprocessor-Controlled Ventilators:

These ventilators use electrical power and advanced software to regulate the respiratory cycle. The Oxylog 3000 and LTV-1000 are examples, offering a range of pressure- or volume-controlled modes adaptable to changes in lung mechanics.

They feature patient-triggered modes to reduce the work of breathing during spontaneous ventilation, often eliminating the need for increased sedation.

These ventilators provide sensitive triggering and rapid delivery of gas flow during assisted breaths, minimizing the work of breathing. They also incorporate features like bias flow during expiration to facilitate rapid response flow sensors.

However, portability compromises, like miniaturized components, can affect ventilator performance. Hence, it's crucial to conduct a trial period on the portable ventilator before transfer to ensure equivalent ventilation.

In summary, while gas-powered ventilators are efficient and suitable for critical care transport, microprocessor-controlled ventilators offer more advanced features and adaptability, making them suitable for a wider range of clinical scenarios.

Electrical Supplies:

Battery Technology: Batteries are often used as a power source for portable ventilators but can be limited in charge capacity and cumbersome. To address this, more energy-dense cells like nickel cadmium, nickel metal hydride (NiMH), and lithium-ion batteries have been developed.

Inverters: Specialist transfer vehicles and some ambulances are equipped with inverters that convert DC from the vehicle battery to a standard 240 V AC supply, providing an alternative power source.

12 V DC Supply: Many road vehicles feature a 12 V DC supply accessible from the cigarette lighter socket, which can be utilized for powering portable ventilators via adapters.

Patient Circuits and Valves:

Breathing Circuits: These circuits carry inspiratory gas from the ventilator to the patient and direct expired air into the atmosphere. They should maintain positive end-expiratory pressure (PEEP) while offering low expiratory resistance to prevent gas trapping.

Valves: Patient valves play a crucial role in regulating PEEP and expiratory resistance. The quality of these components is essential for ensuring adequate ventilation, as poor quality or poorly maintained valves can lead to issues like decreased tidal volume delivery.

Specialist Features: Some ventilators incorporate advanced features like pressure manometers, manual PEEP valves, and microprocessor-controlled sensors to monitor and control ventilation parameters.

Specialist Applications:

Aeromedical Use: Ventilators used in aeromedical settings must contend with the unique challenges of aircraft environments, including hypobaric conditions and electromagnetic interference. They need to be robust enough to withstand engine vibration and compatible with aircraft systems.

Gas Expansion Concerns: Gas expansion within the cuff of tracheal tubes and body cavities can pose risks to patient safety, necessitating careful management during ascent and descent.

Oxygen Supply Considerations: Long-range transportation presents challenges regarding oxygen supply weight and availability. Alternatives like liquid oxygen supplies or built-in oxygen concentrators may be preferable. Ventilators with low gas consumption are advantageous in these scenarios.

Improvised Solutions: In some cases, improvised circle breathing systems can be employed to conserve oxygen supplies effectively.

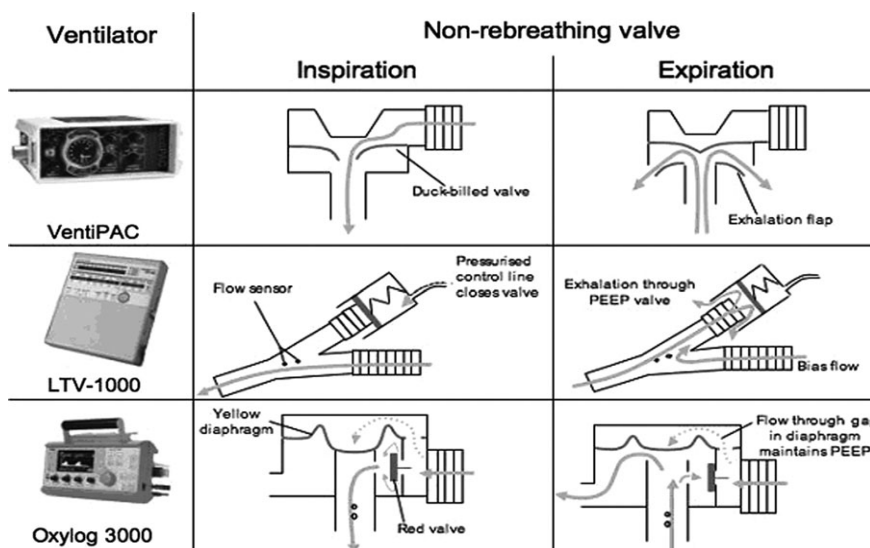


Fig. 1 Non-rebreathing valves within different ventilator breathing circuits.

Paediatrics:

Paediatric patients require ventilators capable of delivering low tidal volumes at increased frequencies, often favoring pressure-controlled ventilation to mitigate the risk of barotrauma.

While ventilators like the VentiPAC, LTV-1000, and Oxylog 3000 can ventilate infants as small as 5 kg, specialized paediatric ventilators are necessary beyond this size range.

Domiciliary Ventilation:

Domiciliary ventilation, particularly beneficial for patients with neuromuscular diseases or respiratory insufficiency, can be provided invasively (tracheostomy) or non-invasively (facemask).

Ventilators like the LTV series, designed for domiciliary use, offer portability and can operate on battery power without compressed gas, making them suitable for mounting on electrical wheelchairs.

Non-Invasive Ventilation:

Non-invasive ventilation, increasingly used for acutely unwell patients during transfer or in chronic disease management, presents challenges related to gas leakage around the mask.

Microprocessor-controlled ventilators compensate for circuit leaks using sophisticated sensors and basal gas flows within the patient circuit, enhancing effectiveness during transport or domiciliary use.

II. CONCLUSION

- Portable ventilators vary in design based on clinical requirements and environmental constraints.
- Provision for estimated gas and electrical needs is crucial when transporting critical care patients, and selecting an appropriate ventilatory mode should be based on the patient's clinical condition.
- Understanding the functionality and limitations of different ventilators can aid in equipment selection and prevent complications during transfer. Comparative data can help organizations make informed purchasing decisions regarding portable ventilators.

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