Ventilators Differ in Their Characteristics, Performance

Transportation of critically ill patients requiring mechanical ventilation requires clinical experience, an efficient device, and careful determination of gases and/or electrical resources. Emergency and transport ventilators (ETVs) should be technically accurate, and as autonomous as possible.

ETVs have become increasingly sophisticated, offering features that were once reserved for the ICU. Noninvasive ventilation (NIV) has become standard during acute respiratory failure in the emergency department (ED) and is now available in most ETVs. However, it requires synchronisation of ventilator cycling to respiratory muscles activity in order to be effective and well-tolerated.

While several studies have focused on ETVs, most of them have only investigated a few devices. The aim of the study by L'Her, Roy and Marjanovic was to provide an objective evaluation of the widest set of ETVs available in Europe and Northern America. The study also aimed to draw standards for an objective choice, taking into account clinicians' specificities of use.

Materials and Methods

This experimental bench-test took into account the general characteristics and technical performance of the ETVs. General characteristics (volume, weight, size, noise) were recorded using standardised techniques. Duration of operation from a battery (electrical autonomy) was assessed after two battery charge/discharge cycles, from ventilation initiation to cessation. Gas consumption was evaluated using a filled oxygen cylinder, until effective ventilation cessation.

Technical performance was assessed under three levels of oxygen inspiratory fraction or FIO_2 (100%, 50% or Air-Mix, 21%); respiratory mechanics: compliance (C) 30,70,120 mL/cmH_2O; resistance (R) 5,10,20 cmH_2O/mL/s; and levels of leaks (3.5 to 12.5 L/min), using a test lung. Asynchrony index (AI) was calculated over a one-minute period, after signal stabilisation, and took into consideration all major types of asynchrony: failed triggering, auto-triggering, prolonged inspiration, multiple triggering, premature and short cycling. AI ≥10 percent of respiratory effort was considered clinically significant.

Twenty-six ETVs were compared and a priori classified according to four categories, taking into account manufacturers' presentation of their devices. ICU-like ETVs (n=5) are devices that, even if transportable, cannot be considered for transportation on a routine basis; sophisticated ETVs (n=10) usually depict curve monitoring screens and allow noninvasive ventilation; simple ETVs (n=9) are standard devices providing no extensive monitoring; mass-casualty/military ETVs (n=2) are devices dedicated for field operations. They are quite heavy and depict little monitoring, but are very robust and may run without oxygen availability.

Parameters were calculated from ≥20 breaths and are given as mean ± SD unless specified otherwise. When adequate, data were compared using analysis of variance (ANOVA) for repeated measures, and the nonparametric Friedman and Wilcoxon ranked tests. A P-value ≤0.05 was considered statistically significant. Differences ≥10% were considered clinically significant.

Results

All 15 ETVs within the ICU-like and sophisticated categories had built-in PEEP valves, and most of them depicted ventilatory curves on a screen. There were 9/15 (60 percent) using a turbine and two using a piston to pressurise gases, which means that they were autonomous from medical gases, but dependent on electrical power; 4/15 (27 percent) within these categories were pneumatic devices (gas-powered), but they were also dependent on electrical power.

The mass-casualty/military ETVs were dependent on electrical power in the compressor mode, but could use solely compressed gases in case of electrical failure. The volume and market price of these devices was usually lower than that of the two first categories.

All ETVs in the ICU-like and sophisticated categories were within the accuracy range for VT, whatever respiratory mechanics combinations, while major deviations were observed in the other categories. Respiratory mechanics influenced VT delivery in all categories and for most devices, except for the simple ETVs, but with huge variations between devices.

Oxygen consumption (7.1 to 15.8 L/min at FIO_2 100 percent) and the Air-Mix mode (FIO_2 45 to 86 percent) differed from one device to the other. Triggering performance was heterogeneous (198 ± 80 versus 256 ± 84 versus 422 ± 206 ms respectively; P = 0.18), but several sophisticated ventilators depicted triggering capabilities as efficient as ICU-like ventilators.

Pressurisation was not adequate for all devices. At baseline, all the ventilators were able to synchronise, but with variations amongst respiratory conditions. Leak compensation in most ICU-like and 4/10 sophisticated devices was able to correct at least partially for system leaks, but with variations amongst ventilators.

Conclusions

A wide evaluation of ETV ventilators was provided on most general features and technical aspects of these devices. As expected, huge heterogeneity in terms of general characteristics and performance were observed. Clinicians should be aware of the significant differences that were found amongst these ventilators when choosing these important devices for initial management and transport of critically ill patients.

Wide variability of tidal volume delivery with some devices in response to modifications in respiratory mechanics and FIO_2 should make clinicians question their use in the clinical setting. NIV capabilities are also highly modified by leaks and their own NIV-mode efficiency. Such a bench-test comparison may also enable the industry to improve its products.

Image Credit: BEI Kimco Magnetics

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