The Smart Pulmonary View from Draeger is an intuitive anatomical analogy that visualises the patient’s pulmonary mechanics.

Breathing life

Latest generation ventilators are user friendly and come in as positive pressure and non-invasive modes, along with microprocessor control and data capture systems

BY RITA DUTTA

Technology

The advancement of ventilator technology is as exciting as it can get. In over a century, the market has seen the advent of negative pressure ventilators to crude totally mechanical devices that could provide only machine triggered volume ventilation to the highly evolved microprocessor controlled systems. In the last decade itself, the ventilator technology has changed from knob-based machines to display-based machines. Says Ganesh Natarajan, general manager, therapeutic care, Philips India Limited. “Today, large displays, dual modes, closed, semi closed loop ventilation and non-invasive ventilation (NIV) have defined the way intensivists ventilate a patient.”

Interestingly, throughout the 19th century and the first half of the 20th century, the negative pressure ventilator was the predominant device used to provide ventilator assistance. Says Dr Vinay Joshi, consultant, NICU, PICU and cardiac ICU, Kokilaben Dhirubhai Ambani Hospital (KDAH), Mumbai, “Negative pressure ventilators were widely used for mechanical ventilatory support until the polio epidemic in the early 20th century. However, negative pressure ventilators were bulky and cumbersome, posed difficulty in accessing the patient on ventilator and were inefficient in severe respiratory failure. This saw the advent of more compact and user-friendly positive pressure ventilators.”

In the early 1940’s and 1950’s, positive pressure ventilators which provided purely volume controlled ventilation became available. In the mid1970’s and early 1980’s, the first patient triggered ventilators appeared. And in the early 80’s through the late 1990’s, ventilators with microprocessor control took over.
Through the 1990’s to the present day, ventilators with a plethora of ventilation modes have become available which also incorporate non-invasive modes of ventilation. Says Dr Vatsal Kothari, director, critical care medicine, KDAH, “Present day ventilators incorporate most new modes of ventilation based on a pressure targeted approach which can determine a respiratory rate and tidal volume combination that results in least work of breathing and maximum patient-ventilator synchrony.” All present generation ventilators are easily up-gradable, include waveforms and provide extensive monitoring of 20-40 variables.

Today, smaller, lighter, portable ventilators have come in vogue. According to Dr N Ramakrishnan, managing director & CEO, InTeleICU, Chennai, “Ventilators have better graphic display. They have also incorporated intelligent data capture systems and some of them have incorporated data analytics and clinical algorithms.” Moreover, some are available with battery backup to provide uninterrupted power supply.

The graphic display of pressure and volume changes over time provides insight on the lung mechanics to the clinician. “The fact that these displays are bold and colourful help the healthcare team to identify changes even from a distance. Inbuilt clinical algorithms ensure patient safety and help the clinicians to identify and manage problems earlier and avoid catastrophe,” says Ramakrishnan, adding that the data capture modules are a boon as they could be used for remote monitoring of patients to provide tele-ICU care which is a much needed service in most countries due to shortage of trained manpower. Incorporating appropriate best practices through these algorithms ensures that the patient receives the highest quality of care.

Experts point out that built-in air source, be it a turbine or a blower, have made huge inroads into the ICU as they afford a greater degree of mobility to the care givers. From standard passive exhala-

dation valves, the market has moved to a dynamic active exhalation valves. “The flow sensors in ventilators have changed from the older differential pressure to the newer electronic flow sensors. The basics of what a care giver needs, however, have stayed the same with lung protection, recruitment, ease of use, low cost of ownership, NIV being standard amongst others. The Philips V-680 actually has world class NIV with world beating invasive features and high end flow sensing technology,” says Natarajan.

Says KV Ramesh, business manager, respiratory care, Dräger Medical India Pvt. Ltd, “Dräger has pioneered the first touch screen operated ventilator, the Evita 4 in 1997, and today many companies use touch screen operation in their devices. Similarly, Dräger pioneered the APRV mode of ventilation in 1992 and today it is being used in treatment of severe cases of ARDS as originally intended. One more advancement by Dräger is ATC (automat-ic tube compensation) in 1999 to reduce the work of breathing for patient.”

Experts say that the most major event in the development of ventilators was microprocessor control, which implied that virtually any approach to gas delivery and monitoring became possible. “It made ventilators markedly more responsive to patient demand and flow triggering became a reality, thus reducing the effort patient needed to activate gas delivery. This also resulted in generation of waveforms (pressure, flow and volume), which provided useful information to the treating physician,” says Dr Kothari. It also resulted in incorporation of more alarms and monitors which not only monitored the patient status but almost every aspect of ventilator functioning.

According to experts, flow sensing has made a tremendous impact on safety in a ventilator. Care givers rely on the values displayed on the ventilator to plan...
The invasion of NIVs

Today, the market is witnessing a surge in non-invasive ventilators (NIVs). Globally, NIV accounts for 30 per cent of all patients ventilated in ICUs. The India numbers are minuscule at present, but increasing to match up to global usage percentages, say experts.

Says Nikunj Gada, managing director, Medion Healthcare, “The non-invasive modes are usually used for less critical patients and as the ventilation is through a mask, it is more comfortable for the patient. Invasive ventilation if used on less critical patients may not be easy for the patient as tubings have to be inserted.”

According to Natarajan of Philips, NIV is the only mode that has shown a measurable reduction in mortality and morbidity in the ICU. Only a few ventilators are able to measure up to the standards of good NIVs due to large leaks. From a technology perspective, the NIV ventilator has to be more sensitive and have a faster response time due to the inherent leaks and varying patient demands.

Dr Vinay of KDAH states that invasive mechanical ventilation is associated with complications like airway injury, lung injury, air leak syndromes (pneumothorax) and ventilator associated pneumonia, leading to increased ICU and hospital stay. “Using non-invasive ventilation (CPAP) where patient is spontaneously breathing, we can avoid above mentioned complications and reduce ICU and hospital stay. NIV is less resource intensive and easy to operate,” says he.

So, how would the ventilators of future be? Experts predict that ventilators would become more compact, intelligent and incorporate newer modes and assist

![The Philips V-680 has NIV with world beating invasive features and high-end flow sensing technology.](image)

therapy for the patient. “The initial flow sensing technology used by most ventilator manufacturers was the differential pressure sensor which, though adequate, was subject to problems due to moisture, secretions and others. This was soon followed by the hot wire technology, which still exists in a few ventilators of today,” says Natarajan. The flow sensing technology is moving towards electronic/ultrasonic to enable a trouble free and extremely accurate flow sensing. “The accuracy of the flow sensing in the Philips V-680 helps the care givers plan therapy and wean patients out faster,” says he.

According to Dr Preetha Joshi, consultant, NICU, PICU and cardiac ICU, KDAH, “Besides microprocessor technology and patient-triggered ventilation, the technological advancements that have made a significant difference is the discovery of surfactant and its role in pre-term respiratory distress syndrome, high frequency ventilation - a newer mode which helps in severe respiratory failure and inhaled nitric oxide that opens up the vessels in lungs that fail to transition from fetal to neonatal life.”

The other technology shift is the response time and the ability to measure respiratory mechanics. Most of the high-end ventilators today give both static and dynamic compliance, resistance along with plateau pressure and Elastance in any mode. This helps the care giver to ensure safe breath delivery to the patient.

“In the current era, we can’t think of ventilators without in-built pulmonary graphics. Newer techniques like Neuromuscular Adjusted Ventilator Assistance (NAVA) help in better synchronisation and optimum delivery of pressure support depending upon lung pathology and patient effort, thereby reducing ill effects of positive pressure ventilation,” says Dr Vinay, adding that the ability to measure trans-pulmonary pressures and guide the ventilatory support helps to deliver lung protective ventilation. The use of recruitment tool and ClO2, automated control of neonatal oxygenation with every breath) help to reduce ventilator and oxygen induced lung injury.

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GANESH NATARAJAN, GENERAL MANAGER, THERAPEUTIC CARE, PHILIPS INDIA LIMITED
The flow sensing technology in ventilators is moving towards electronic/ultrasonic.

The clinician with decision making based on actual data of cardiorespiratory mechanics. “My vision is to see a clutter-free wireless ICU with a single equipment at the bedside that could incorporate the functions of all the commonly used equipment such as cardiac monitor, ventilator and fluid management pumps. What would also add value is direct capture of all these data in the electronic medical record and intelligent analytics to automatically make the necessary changes. If technology could take care of all these aspects, the clinician and other healthcare professionals could focus on the true art and science of medicine rather than spending enormous time in manual entry of data and related documentation,” says Dr Ramakrishnan.

According to Dr Sunil Karanth, head, critical care medicine, Manipal Hospitals, Bengaluru, the ventilator technology will only get smarter in the years to come. “Soon, we should have a ventilator system that helps in shortening patient stay in the ICU,” says he.

According to experts, there has to be integration with bedside technology, ability to effectively ventilate all patients in all settings, invasively or non-invasively, ventilator management protocols incorporated in basic operation of the ventilator, smart alarm systems, display of information instead of unrelated data. “In decision support, each alarm condition will be followed with a listing of potential causes and potential solutions. Closed loop ventilation should be available on all modes and new ventilators will be able to adjust gas delivery to improve patient-ventilatory synchrony,” says Dr Kothari.

Experts say that respiratory profile monitoring is one trend that will have an impact on patient outcomes. “The ability to measure cardiac output non-invasively on a ventilated patient is gaining interest. Semi closed loop ventilation will also interest the purists. Connectivity between the ventilators and other devices in the ICU like monitors will also be a technology to watch out for. Newer platforms from Philips are already being designed to have a lot of inter product connectivity,” says Natarajan.

According to Ramesh of Dräger, more than the modes of ventilation, the future would be about intuitive recognition of data through medical cockpits. “Rather than seeing lots of numbers, pictorial representation of the lung data - such as Dräger’s Smart Pulmonary View - would be the way ahead. Additionally, independence from air source, through internal turbines, rather than bulky compressors, would also be a development as more and more devices are bought in tier II and tier III cities,” says he.

The future ventilators should be able to interpret the airway pressure and flow waveform during both volume and pressure ventilation and to automatically adjust the flow waveform, peak inspiratory flow, rise time and termination criteria to ensure that gas delivery is synchronous with the patient’s requirements. One needs to provide integrated information and interpretation of alarms and data variables rather than unrelated data. One also needs to ensure fewer false alarms by having smart alarm systems to reduce noise pollution and alarm fatigue in medical staff.