If Breathing Fails – Intensive Ventilation Devices are Lifesavers

The rhythm of life is determined by breathing in addition to our heartbeats. When inhaled air passes through the lungs and blood reaches the body's cells, this air is part of an exchange process and exhaled as carbon dioxide.Breathing, however, is not only a biochemical process, it can also vary from situation to situation and thus affect our everyday life: Short successive breaths can dispel fatigue, while breathing slowly relieves stress and breathing deeply helps to optimize the performance of muscles, organs and the brain. But what happens if we can no longer breathe on our own? Is it possible for a device to do this for us and to adjust to a patient if the breathing is restored?

From a wooden case to the iron lung

The basic idea behind the first ventilation devices was to provide the lungs with as much oxygen as possible to simply save lives. A good example is an unconscious young man pulled from the waters of the River Thames in London by firefighters in the early 20th century who attempted to revive him on shore with motion exercises. When Johann Heinrich Dräger observed the situation, he started thinking along the lines of a ventilation device, which would provide oxygen for emergency breathing immediately on site. His Pulmotor developed in 1907 was the first series-produced emergency ventilator in the world. The inspiration and exhalation strokes emitted by this small machine that fits into a wooden case could not yet be adjusted variably but were controlled by a modified clock movement with cam.
Subsequent designs, such as the "iron lung" developed in the 1920’s, function as an artificial diaphragm and supply the lungs with fresh air by generating a preset artificial high and low pressure. The mouth and nose are not covered by a mask. A major disadvantage of these ventilators: The supine body is completely encased in an airtight capsule, all but the head, which is protruding from one end. The patient is able to communicate with voice and eye contact but is severely restricted concerning gestures and any other mobility. Many patients spend years or even decades of their life in the "iron lung" – such as June Middleton, who for 60 years had to use the life-sustaining tube for 21 hours every day and died in 2009. But the development of artificial respiration does come to a stop on the technical level of these bulky metal hulks.

"Iron lung": unwieldy lifesaver – for some people a lifetime spent encased.

D-9191-2009

**When is artificial ventilation necessary?**

A ventilation device may be required not only as part of a general anesthetic in the context of a surgical procedure but also injuries to the chest, diseases of the airway, and gas exchange or lung disorders often require artificial respiration. In general, all indications requiring mechanical ventilation are classified under the heading of acute lung failure. This includes such diseases as chronic obstructive pulmonary disease (COPD), often a result of excessive smoking, and severe forms of asthma. Both diseases include hypercapnic respiratory failure, a condition in which the carbon dioxide content of the blood is too high due to chronic insufficient breathing. These are differentiated from diseases in which the oxygen content of the blood is too low due to a disturbance of the oxygen supply to the lungs (hypoxemic respiratory failure). This is the case with an acute lung injury (ALI), for example, caused by pneumonia (lung infection) or trauma and in acute respiratory distress syndrome (ARDS).
Breathing naturally with computer technology
Today, medical technicians know much more about the requirements of the lung during ventilation, about how to best support natural breathing and how to wean the patient from artificial respiration when no longer required. Modern ventilation devices must have primarily three key functions: They supply the patient with fresh air, they take over some or all of the patient’s breathing, and they alert caregivers to changes. These may include, for example, patient-side changes such as an increase in airway resistance or a deterioration of the elasticity of the lungs.

One of the major challenges in respiratory therapy is to allow early spontaneous breathing. This means patients are able to inhale or exhale on their own at any time, independently from the actions of the ventilator. This was made possible in the late 1980’s by the implementation of electromagnetic valves and ventilation controllers with microprocessors. The first ventilator that allowed patients to breathe spontaneously during mechanical ventilation at any time was Evita. In 1988, Dräger launched this device equipped with the pressure-controlled BIPAP (Biphasic Positive Airway Pressure) system. Another function used by Evita 4, which Dräger launched about ten years later, was able to measure the respiratory volume of the patient every eight milliseconds and automatically regulates the ventilation pressure, which is called Proportional Pressure Support (PPS). Within a breathing cycle lasting only a few moments, the device adjusts the pressure more than one hundred times.
Ventilation with pressure or volume?
Pressure-controlled ventilation requires that the physician sets a specific respiration pressure on the ventilator, which is then used by the device to "press" breathing gas into the lungs. In contrast, volume-oriented ventilation is based on the amount of applied breathing gas, the so-called tidal volume. Pressure-controlled respiration was derived originally from the volume-oriented ventilation. However, pressure-controlled and volume-controlled respiration coexist today as the basic principles of mechanical ventilation.

The significance of this improvement, achieved with the help of computer technology and a continuous ventilation monitoring, is especially clear in comparison to the methods used in clinical practice. Until the 1980’s, the nurses in the ICU had to use drugs to suppress the breathing of patients so as not to impair the functions of the ventilator. For patients, this resulted in more physical and mental stress during the weaning phase if they were unable to exhale during the mechanical strokes of the machine.

The device listens to the patient
With spontaneous breathing, the device notices when the patient wants to inhale. The breathing strokes do not have a fixed interval predetermined by the machine. The breathing stroke frequency of the device is based, among other things, on the spontaneous breathing of the patient. This is accomplished by an adjustable flow trigger, a trigger function. When the inspiration effort of the patient exceeds a certain threshold, the breathing gas supply is triggered. Respiration takes place either invasively through a tube or non-invasively with a facial or nasal mask. An improperly fitting mask may result in leaks with escaping breathing gas, especially during non-invasive ventilation. The ventilation device should be able to distinguish these leaks from actual inspiration impulses and to always add automatically as much breathing gas volume as lost through the leak. The advantage: The patient is supplied with the right amount of breathing gas inspite of the leak.
Mechanical and yet as gentle as possible

The first mechanical ventilators with fixed breathing strokes could not yet take into account the possible side effects of ventilation on the sensitive lung tissue. Technology was unable to do this for many years. In 1995, however, the intensive care ventilator Evita 4 by Dräger introduced the volume-controlled autoflow method, which made it possible for the first time to adjust to changes in lung function during mechanical ventilation. If, for example, the lung tissue becomes more elastic during the ventilation process, the device is able to detect this and lowers the ventilation pressure automatically. At the same time, it maintains the required volume\textsuperscript{xxii} and allows the patient to breathe freely at any time. The process also eliminates critical pressure peaks, thereby protecting the sensitive lung from damage caused by excessive ventilation pressure. Since 2011, a solution suitable for the clinical routine is also available for the first time, which continuously monitors the distribution of ventilation volume in the lungs, directly at the bedside. This is made possible by the electrical impedance tomograph PulmoVista 500. This technology allows physicians to adjust settings on the ventilator continuously to the particular situation of the patient and, thus, ventilate the lungs as gently as possible (see also background text "Gentle pulmonary respiration").\textsuperscript{xxiii}

**Natural breathing versus mechanical ventilation**

The diaphragm moves down and the chest expands during natural breathing. The resulting negative pressure causes fresh air to flow in the direction of the lungs. Machine (controlled) ventilation uses positive pressure to push breathing gas into the lungs.\textsuperscript{xxiv} We can distinguish between four mechanical ventilation modes: controlled, synchronized, supporting spontaneous, and spontaneous. During controlled ventilation without the patient contributing, the ventilator takes over all of the breathing normally done by the patient. This is necessary if natural breathing is no longer possible, for example, during anesthesia.\textsuperscript{xxv} During synchronized breathing, patients are able to trigger ventilator strokes within a fixed time window with their own breaths. If no breathing effort is detected, the device reverts to mechanical ventilation strokes. The third form of respiration, supporting spontaneous breathing, is detected by the ventilator as a breathing effort of the patient. As soon as patients try to breathe on their own, the device supports their efforts by raising the airway pressure in the respiratory system\textsuperscript{xxvi}. Spontaneous respiration describes not only natural breathing but also independent breathing on a respirator at a positive airway pressure level.\textsuperscript{xxvi}

**Requirements for ventilating the smallest patients**

Infants born before the 37th week of pregnancy are called premature babies. Very undeveloped preemies, as they are also called, and most preemies born...
between the 27th and 29th week of gestation require mechanical ventilation. The reason is that the lungs of these babies are not yet fully developed. Their body does not yet produce enough surfactant – a substance that ensures the alveoli develop after birth and do not collapse. With the help of a slight positive pressure, ventilation devices are able to open and keep open the alveoli. Small tidal volumes and high respiratory rates of the comparatively tiny respiratory system are the special medical challenges faced when ventilating preemies. Specially developed ventilation devices are therefore available for babies.

The Babylog 8000 by Dräger was the first ventilation device for preemies featuring an integrated volume monitoring function. This allowed for an accurate diagnosis of the sensitive lung function and a correspondingly fine-tuning of the ventilation pressure. The Volume Guarantee function responds automatically to changes in lung function, for example, when a surfactant dose reduces the tension of the bubbles. This prevents the risk of over-stretching the lungs. The pressure support is now optimized so that babies not only determine the start of inspiration but also the moment of expiration and, thus, breathe freely at any time.
Presskit – background article: Intensive care ventilation

July 2012

More online information on the basics of breathing and intensive care ventilation is available at our website: www.draeger.com/academy-ic

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