Mechanical Ventilation, A Historical Perspective

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"But so that life may in some measure be restored to the animal, you must attempt an opening in the trunk of the trachea and pass into it a tube of rush or reed, and you must blow into this so that the lung may expand and the animal draw breath after a fashion; for at a light breath the lung in this living animal will swell to the size of the cavity of the thorax, and the heart take strength afresh and exhibit a great variety of motions".
From "De humani coporis fabrica" by Andreas Vesalius (1543).

450 years of experimental pulmonary physiology

This translation from the original Latin text is the first account of mechanical ventilation and also the first description of the physiological effects produced when the technique is applied after lung collapse is induced by piercing "the inner lining of the ribs". The experiment was performed on a pregnant sow (Figure 1) by Andreas Vesalius and reported in the last chapter of his famed anatomical treatise "De humani coporis fabrica" published in 1543.

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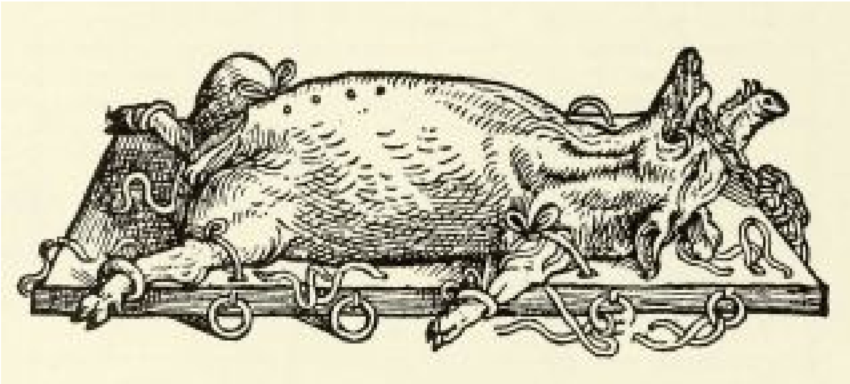

Figure 1: The first account of mechanical ventilation (From the publication of Vesalius by A.Gedeon)

This seminal publication revolutionized anatomy and by replacing millennia of dogma with careful observation of the body structures, it also ushered in an entirely new era in medical investigations. It is a remarkable coincidence worth noting that the very same year, 1543, Nicolas Copernicus´s work "De revolutionibus orbium coelestium" was posthumously published, with the radical suggestion that the geocentric system of the planets, conceived by the ancients, should be replaced by a heliocentric model; in other words a total change of view about man's place in the universe.

17th century academies advance scientific approach

During the following century these groundbreaking ideas evolved into a more general scientific approach that was soon applied to many fields of study and, particularly through the formation of scientific Academies, quickly generated new insights that often challenged traditional beliefs.

One of the oldest of these Academies and arguably the most prominent was the Royal Society in London. At its regular meetings, a specially appointed member, Robert Hooke, was requested to make some thought provoking experiments or demonstrations. Hooke, who today is probably best known for the law named after him (that relates the force of a spring to its distension) was a man of wide-ranging interests and great originality.

As described in the Proceedings of the Royal Society under the heading "Preserving Animals Alive by Blowing through their Lungs with Bellows" he performed an experiment on October 24, 1667 where he connected a dog with open thorax to two bellows. Using one bellows only he demonstrated that the "the supply of fresh Air" can keep the dog alive for hours while "the bare Motion of the Lungs without fresh air contributes nothing to the life of the Animal". Using the second bellows to produce a positive pressure through rapid pumping and then perforating the lungs he showed that the continuous flow of air alone is sufficient to keep the dog alive.

This fact was rediscovered by Samuel Meltzer about 250 years later while working on an early model of a positive pressure ventilator.

New resuscitation methods promoted

In 1767, a century after Hooke´s remarkable experiments, a group of wealthy merchants in Amsterdam decided to form a Society to promote better methods for saving "drowned persons". They did this by publishing guidelines for proper resuscitation procedures and by offering generous awards to those successful in saving victims.

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Their ideas quickly caught on in other countries and within a decade organizations with similar aims were established in most major European cities with waterways. A historical account of these rapid developments was published in 1796 by two Danish physicians, Johan Herholdt and Carl Rafn, who were also the first to propose the use of the newly discovered gas oxygen to improve resuscitation outcomes.

A typical equipment kit used in the 1770s to revive the "apparently dead" is shown in Figure 2. According to the recommended procedure the bellows was to be used to blow air or smoke into the lungs or up the rectum.

Figure 2: Tobacco resuscitator kit, late 18th century. Science and Society Picture Library. The Science Museum, London, U.K. (by permission) [2]

It should be noted that highly successful mouth-to-mouth resuscitation was reported by John Fothergill already in 1744 but this technique fell into oblivion only to be reintroduced with great success little more than two centuries later.

Preventing lung barotrauma

Perhaps not surprisingly, the use of bellows in emergency situations could easily cause rupture of the lungs, and in 1827 Jean Leroy d´Etoilles felt the need to improve the design so that the pressure produced by the bellows could be limited to safer levels. To eliminate the risk of barotrauma entirely, Eugéne Woillez constructed in 1876 the first whole body negative pressure device that he called the "Spirophore" (Figure 3).

The periodic suction was produced by a manually operated mechanical lever and the patient's chest and abdomen were observed through a transparent window in the tube that enclosed the body but left the head free. Further monitoring of respiratory movement was provided by a movable rod sliding in a vertical tube (marked "E" in Figure 3) and resting on the patient's sternum.

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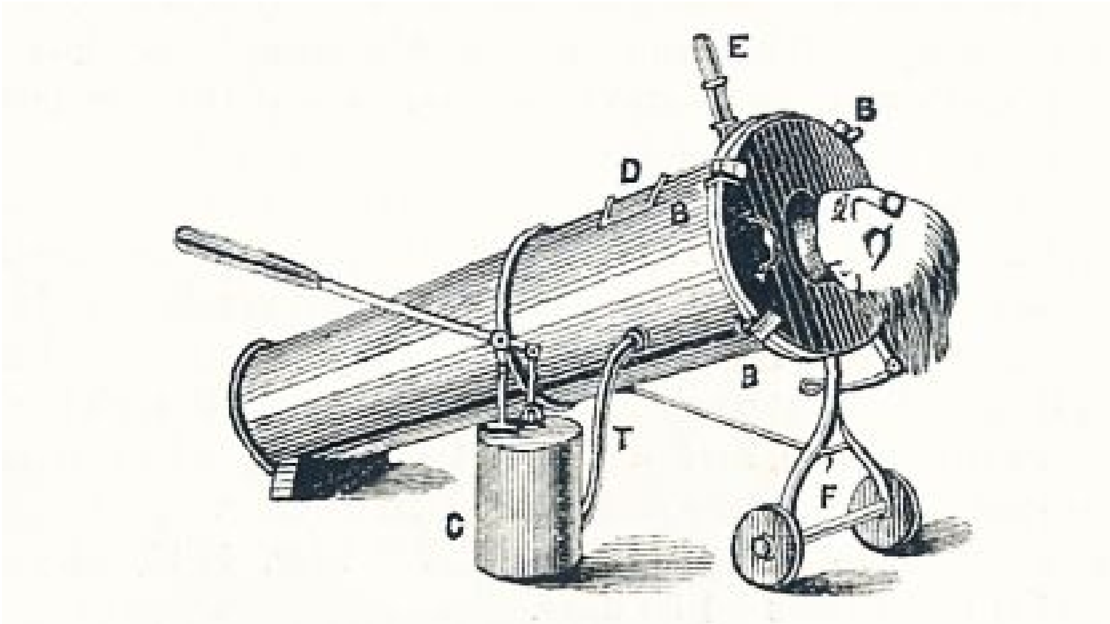

Figure 3: "Spirophore", the first whole body negative pressure device, constructed in 1876 (From Woillez's original publication by A.Gedeon)

Inhalation agents rediscovered

The dramatic rediscovery of the anaesthetic effects of ether in the 1840s (a phenomenon first described almost 300 years before by Paracelsus) was instantaneously put to use in surgical theatres around the world. However, the administration of inhalation anaesthetics (particularly chloroform) resulted in many fatal outcomes due to lack of knowledge about the inhaled dose.

To improve on this situation John Snow soon developed new equipment and methods for delivering these anaesthetics in a more controlled way. He investigated the physical and chemical properties of the substances and studied their physiological effects, thus placing anaesthesiology on a firm scientific footing.

He also performed, on a rabbit, the first intratracheal anaesthesia with manual ventilation. The first endotracheal anaesthesia on a human took place in 1907 during a facial operation in Lyon with equipment built by Marc Barthélemy and Léon Dufour.

Emerging positive pressure ventilation

Further advances in mechanical ventilation and endotracheal anaesthesia required better and more reliable ways to connect the patient to the ventilating device.

A first step in this direction was taken in 1871 when the cuffed tube was introduced by Friedrich Trendelenburg. A surgeon, he invented the device to prevent aspiration during surgery of the larynx. During the very first years of the 20th century, Franz Kuhn developed practical devices and techniques for oral and nasal intubation that were also well suited to positive pressure ventilation.

Benefiting from these advances, Samuel Meltzer and Charles Elsberg presented a decade later the first clinically useful ventilator equipment for intratracheal insufflation that marked the beginnings of modern endotracheal anaesthesia.

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Scandinavian breakthroughs in the 1950s

During the first half of the 20th century both positive pressure devices and negative pressure devices ("iron lungs" like the Spirophore and cuirass ventilators enclosing only the thorax) were in clinical use for ventilating patients. The Scandinavian polio epidemics during the first years of the 1950s would change all this, however.

The new development came from the realization, based on repeated blood gas analysis, that negative pressure apparatus frequently failed to provide adequate ventilation for polio patients leading to CO2 retention and ultimately to death. In 1950 Carl-Gunnar Engström was the first to report these observations and he also went on to construct a positive pressure ventilator that could properly ventilate the victims of polio. Soon the device found many new uses, in diseases of other aetiology than poliomyelitis, where the patient benefited from long-term mechanical ventilation.

The 1950s polio epidemics gave rise not only to a new era in mechanical ventilation but also to rapid progress in another related area, that of blood gas analysis. Quantitative blood gas analysis was first performed by Gustav Magnus in 1837 but the technique remained largely a research tool confined to the laboratories.

However, during the 1950s, new sensor technology emerged in response to the clinical need to assess the status of patients on mechanical ventilation. Blood gas analysis became fully automated and widely available during the 1970s, and ever since that time it has played an important role in clinical medicine in general and in the advancement of ventilator treatment in particular.

The history of mechanical ventilation extends over more than four and a half centuries. Whether the technique is used in emergency situations, in intensive care or during anaesthesia the glimpses of the evolutionary process given above hopefully illustrate the intricate paths leading up to the practices of today.

References

[1] This paper is based on material from:
Andras Gedeon: Science and Technology in Medicine. An Illustrated Account Based on Ninety-Nine Landmark Publications from Five Centuries. 551 p., 1100 illus., Hardcover ISBN-10: 0-387-27874-5. Copyright 2006 Springer Science+Business Media Inc.
See also: http://www.scienceandtechnologyinmedicine.com

[2] Tobacco resuscitator kit, late 18th century. Science and Society Picture Library. The Science Museum, London, U.K. (by permission).
Legend for the picture (ref. 10317582):"This apparatus was used to revive people who were apparently 'dead', by making use of tobacco's stimulant qualities. The bellows were used to blow tobacco smoke up the rectum, or into the lungs through the nose or mouth. Tobacco enemas were popular from the 17th to the early 19th century. " http://www.scienceandsociety.co.uk

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