Artificial lung ventilation

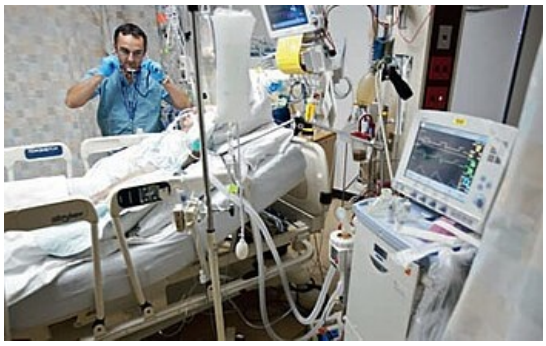
This article discusses the general use of UPV in intensive care. Other articles related to the topic: Introduction to artificial pulmonary ventilation • Artificial pulmonary ventilation (neonatology) • Artificial pulmonary ventilation/SŠ (nursing).

Artificial pulmonary ventilation (UPV) is a method of breathing in which the flow of gases through the respiratory system is fully or partially ensured by a mechanical device. UPV is used short-term or long-term in situations where it is necessary to support the respiratory system of patients who have developed a serious ventilation or oxygenation disorder or are at risk of developing this disorder . UPV can be conducted in a non-invasive way, which uses different masks, or in an invasive way, for the use of which you need an adequate securing the airway for example, by means of endotracheal intubation or tracheostomy

racheostomy.

Indication

UPV should be considered if there are clinical or laboratory **signs of inadequate oxygenation or ventilation**. Consideration of UPV must take into account the overall condition of the patient and is very **individual** . We evaluate the nature of the underlying disease, prognosis, risks and response to conservative therapy. Therefore, the indication criteria differ in different sources.

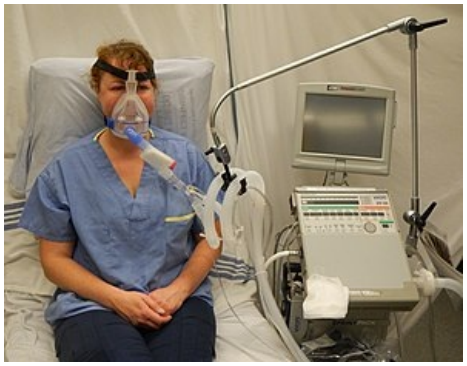


Patient on UPV in intensive care unit

Criteria for the use of UPV

prof. Ševčík	**prof. Hall**[1]
P_aO_2 < 70 mmHg při F_iO_2 > 0,4	S_aO_2 < 90 % při F_iO_2 > 0,60
DF > 35/min	DF > 30/min
P_aCO_2 > 55 mmHg	P_aCO_2 > 50 mmHg
apnoe	pH < 7,25

A specific group of indications is protection against the ***risk of aspiration*** in patients with altered consciousness (overdose, craniotrauma) or a condition increasing the risk of aspiration of the GIT (bleeding from esophageal varices).



Non-invasive positive pressure pulmonary ventilation (*NPPV, NIV*)

UPV is also indicated for pharmacologically induced respiratory insufficiency, especially in the context of general anesthesia management *(together with airway protection in case of impaired consciousness).*

Examples of conditions associated with the necessity of UPV in intensive care

- **Processes filling the alveoli** – pneumonitis (infectious, aspiration), non-cardiogenic pulmonary edema/ARDS (infection, inhalation trauma, drowning, post-transfusion, contusion, altitude sickness), cardiogenic pulmonary edema, pulmonary hemorrhage, tumor (e.g. choriocarcinoma), pulmonary alveolar proteinosis, intravascular hypervolemia.
- **Pulmonary vessel disease** – pulmonary thromboembolism, amniotic fluid embolism, tumor embolism.
- **Central airway obstruction** – tumor, angioedema of the larynx, tracheal stenosis.
- **Distal airway obstruction** - exacerbation of COPD, acute severe asthma.
- **Hypoventilation from central causes** – general anesthesia, drug/addictive drug overdose.
- **Hypoventilation from peripheral neuromuscular cause**s – ALS, quadriplegia, Guillain-Barré syndrome, myasthenia gravis, tetanus, toxins (strychnine), muscular and myotonic dystrophies, myositis.
- **Hypoventilation for diseases of the chest wall and pleura** - kyphoscoliosis, trauma (fluttering chest), massive pleural effusion, pneumothorax.
- **Increased ventilatory requirement** – severe sepsis, septic shock, severe metabolic acidosis.

Goals of ventilatory therapy

The ACCP conference in 1993 divided UPV targets into physiological and clinical as follows[2].

- **Physiological targets** include :
  - manipulation of gas exchange in the lungs,
    - support of alveolar ventilation (manipulation of P and CO_2 and pH),
    - support of arterial oxygenation (manipulation of P and O_2 , saturation of arterial blood with oxygen),
  - affecting lung volumes,

        - increasing lung volume at the end of inspiration or maintaining functional residual capacity,
    - reduction of work of breathing,
        - synergy with the work of respiratory muscles.
- The main clinical objectives include:
    - reversal of hypoxemia,
    - reversal of acute respiratory acidosis,
    - reversal of respiratory distress.

In some patients, additional UPV targets may be established. A special case of using UPV is the administration of **inhalation anesthesia**.

Types of UPV

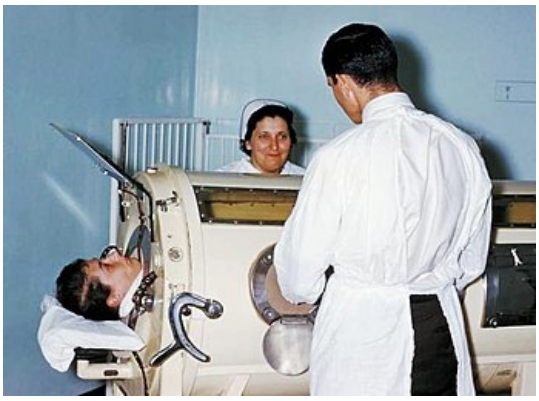
According to the gas flow mechanism, we divide UPV into the following 4 groups:

Overpressure ventilation,

This is the **most widespread type of** UPV, the so-called **"conventional ventilation"**, we use breathing frequencies close to physiological ones and the size of the breathing volume larger than the size of the dead space. The size of the required pressure is determined by the required flow rates, the compliance of the chest and lungs, the resistance of the ventilation circuit and the size of the end-expiratory alveolar pressure.

vacuum ventilation,

The so-called iron lungs were previously used more often, today they have limited indications, for example in patients with neuromuscular disorders, thereby avoiding the risk of complications associated with airway management. [3]


Vacuum ventilation

jet ventilation,

It uses a frequency of around 150 breaths per minute, while the air is forced into a narrowed part of the circuit (nozzle). This increases the speed of air flow, which thus reaches the alveoli. It thus enables effective ventilation to be maintained even when the airways are open, for example in **thoracic surgery** for procedures on the trachea, ventilations for bronchopleural fistula or bronchoscopies under general anesthesia.

oscillating ventilation.

It uses higher frequencies (3 to 15 Hz) and very small volumes, which enables the maintenance of practically constant pressure in the alveoli . It is used, for example, in **UPV in neonatology** with homogeneous lung damage . [4]. In adult patients, it can be used in ARDS, therapy , but not as a first-line therapy .

Jet and oscillatory ventilation methods use very low ventilation volumes and high respiratory rates, thereby reducing the risk of lung barotrauma. [5] Together, they belong to the group of so-called high- **frequency ventilation - HFV** .[6].

Conventional UPV mechanism

The breaths that are present during UPV are divided into 4 basic types: **controlled** breath (breath fully controlled by the ventilator), **assisted** (breath is initiated by the patient, but its further course is fully controlled by the ventilator), **supported** (ventilator increases the inspiratory flow in otherwise controlled breathing patient) and **unsupported** . The course of one ventilation cycle is divided in the following way according to the direction of movement of gases through the respiratory system.

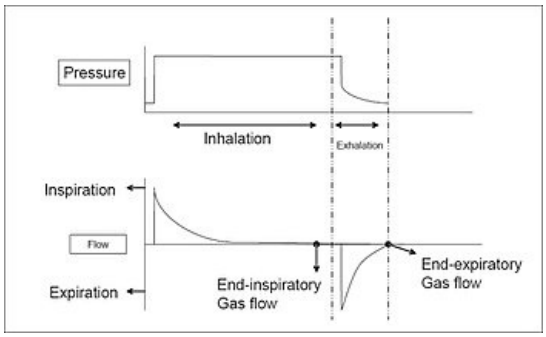
Breathing cycle

1. **Inspiratory phase**:
    - **Initiation** – the signal for the start of the cycle.
        - Set time (with a set respiratory frequency of 15/min, the ventilator starts once every 4 seconds)
        - A change in the pressure in the circuit or a change in the flow of gases (by the patient's effort). When triggering (triggering) according to a change in pressure, it also depends on the refractory capacity of the lungs affecting the speed of expiration - the inhalation is triggered only at the moment when the pressure in the lungs drops below the set limit during exhalation. The required level of sensitivity can be set on the ventilator in case of triggering by the patient's efforts.
    - **Limitation** – value of pressure or tidal volume after which the inspiratory phase ends.
    - With controlled breathing, it is first necessary to increase the pressure at the point of entry into the airways to achieve a sufficient value by so-called "pressurization", i.e. reaching alveolar pressure, further increasing the pressure in the circuit leads to air flow into the lungs.
2. **Inspiratory pause :** Helps to stop the controlled movement of gases in sufficient redistribution in the airways.
3. **Expiratory phase :** The ventilator does not work, the patient exhales passively or with the participation of

expiratory muscles.
    - One of the basic settings of the ventilator is the ratio of inspiration to expiration (**I:E**), which enables regulation, for example, by prolonging expiration in obstructive disorders (asthma bronchiale).
4. **Expiratory pause** : This phase is delimited by the end of the airflow during expiration and the initiation of a new cycle in the inspiratory phase.

Classification of ventilation modes

Ventilation modes can be classified according to several criteria. According to synchronization with the patient's breathing, they are divided into **synchronous** (breaths are initiated by the patient's effort, most adult UPV modes) and **asynchronous** (most often used in neonatology). Modes can also be classified according to the degree of respiratory support, which can range from simple pressure support of spontaneous breathing to ventilation fully controlled by the device without spontaneous patient activity.



Connection between system pressure and gas flow through the UPV circuit

We usually divide the ventilation modes as follows:

- **modes with a set size of breathing volume** (so-called *volume-controlled* or *volume-limited*),
    - these modes are suitable if the main goal of UPV is a constant amount of minute ventilation, i.e. most often P CO2 control
    - ***VCV*** (*A/CMV*, *volume-controled ventilation*) – all breaths have an identical fixed set breathing volume and are either initiated by the ventilator after a certain time or by the patient's own effort (pressure/flow),
        - often used initial mode, especially in anaesthesia, to ensure sufficient breathing volumes and ease the patient's work of breathing,
    - ***SIMV*** (*synchronized intermittent mandatory ventilation*) – to the ventilator-controlled breaths with a fixed volume, the patient can add his own breath not controlled by the ventilator, with a larger or smaller volume,
- **modes with a variable tidal volume** (so-called *pressure-controlled* or *pressure-limited*),
    - the advantage of these modes is "autoregulation" of reactions to pressure changes in the patient's respiratory system,
    - ***PCV*** (*PC A/CV*, *pressure-controlled ventilation*) – all breaths (initiated by the patient or the ventilator) lead to an increase in the pressure in the circuit to a set value, which leads to a tidal volume dependent on the compliance of the lung tissue,
    - PC SIMV – ventilator-controlled breaths as in PCV, the patient can add his own breaths with his own volume,
    - **pressure support ventilation** (*PSV – pressure support ventilation , marked SPONT* on some ventilators) – UPV supplies pressure support that increases gas flow during inspiration, the beginning of breathing and the resulting breathing volume depends on the patient's own effort,
    - SIMV with pressure support – to the own breaths present in both types of SIMV, pressure support can be added as in PSV,
    - BiPAP (*biphasic positive airway pressure*, *DuoPAP*) – the patient ventilates with continuous positive airway pressure (*CPAP*), but the ventilator alternates higher and lower levels of pressure for inhalation and exhalation synchronized with the possible breathing effort of the patient. The mode allows a smooth transition between spontaneous breathing under positive pressure (like *PSV*) and a controlled mode similar to *PCV* .
- **Pressure vs Volume**[7]
    - No difference in mortality, oxygenation or work of breathing.
    - The advantage of pressure-controlled ventilators is the achievement of lower peak pressures, more homogeneous distribution of gases, better synchronization of the patient with the ventilator and faster weaning from the ventilator.
    - The advantage of volume-controlled is the guarantee of a constant respiratory volume and therefore minute ventilation.
- **New ventilation modes**
    - Due to the proliferation of microprocessors, today's ventilators allow the use of various more complex ventilation systems. These enable, for example, a guarantee of a certain breathing volume at a more physiological pressure course of breathing than with classic VCV thanks to the automated measurement of lung compliance. Unlike the previous models, which are usually found in all ventilation devices, the new ventilation modes tend to be specific to a certain manufacturer. These include modes such as *ASV* , *PRVC* or *PAV* .

PEEP

🔎 *For more information see PEEP.*

The abbreviation **PEEP** stands *for positive end expiratory pressure* . Its inclusion in the ventilation regime is today one of the basic components of UPV for several positive effects. **It increases the FRC** (functional residual capacity) of the lungs, thereby reducing the risk of compressive atelectasis. It also **limits lung** shearing damage from repeated alveolar collapse and aeration when using high peak pressure but low PEEP ventilation. In patients with a significant disorder in the uniform distribution of respiratory gases (e.g. COPD) , it **increases the**

homogeneity of the distribution. The use of PEEP in patients in whom there is a restriction of flow (collapse) of the airways during the respiratory cycle causes them to stiffen at the end of expiration and **facilitate the beginning of inspiration** .

Commonly used values are in the range of 3–5 cm H 2 O for preventive use [8], but in severe ARDS the values can range up to 15–20 cm H_2O[9].

The use of PEEP has no absolute contraindications, but it should be used especially at high values with caution in patients with intracranial disease, unilateral focal pulmonary process, hypotension, hypovolemia or bronchopleural fistula[8].

Intrinsic PEEP

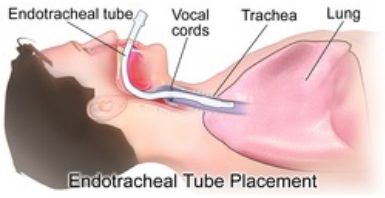
Intrinsic PEEP, also **auto-PEEP** , is the result of insufficient exhalation and subsequent progressive air-trapping (retention of air in the lungs). The cause may be too **high minute ventilation**, **expiratory resistance** (bent intubation cannula), **obstructive disease** (asthma). It increases the risk of barotrauma or hypotension. The treatment consists primarily in the modification of the precipitating condition.[8]

Overview of basic UPV setting parameters

- **Ventilation mode**
- **V_T** (TV) – volume of one breath (usually approx. 7 ml/kg of ideal weight)
- **PEEP** – 3-5 cm H 2 O as standard
- **FiO_2** – fraction of inhaled oxygen, minimum 0.3 (30%)
- **Respiratory rate** (RR, f) - normally 10-14/min
- **$P_{plateau}$**, $P_{support}$, P_{high}, P_{insp}, PIP, ... – pressures regulating the course of pressure-controlled breaths in various ventilation modes, set according to lung compliance so as to lead to adequate breathing volumes with minimal risk of lung damage by barotrauma
- **I:E** – ratio of inhalation to exhalation – normally 1:2, asthma approx. 1:4, ARDS 2:1
- **Trigger** –the sensitivity of the sensors capturing the patient's own effort to inhale – usually about -2 cm H 2 O or a flow rate of 2 L/min

Adverse effects and complications of UPV

Adverse effects can be divided into pulmonary and extrapulmonary. Furthermore, depending on the origin of the ENT, we divide it into the consequences of securing the airways, the consequences of the UPV itself, and the consequences of immobility and related problems. UPV is also associated with a higher risk of infectious complications due to the deterioration of the function of mucociliary transport during the provision of DC, the use of sedative drugs and positive pressure ventilation itself.



Endotracheal cannula

The presence of an endotracheal tube causes an increased risk of:

- sinusitis (without great clinical significance),
- ventilator pneumonia,
- tracheal stenoses,
- damage to the vocal cords,
- very rarely tracheo-esophageal or tracheo-vascular fistulas.

Complications of mechanical ventilation include:

- pneumothorax (in combination with acute hypotension, tachycardia or a sudden increase in maximum inspiratory pressure, one should think about the acute onset of **tension pneumothorax**),
- oxygen toxicity,
- decrease in urine excretion,
- affecting liver and gastrointestinal functions,
- reduction of venous return and afterload by pressure changes, can lead to hypotension
- VALI (*ventilator-associated lung injury* – lung damage associated with UPV).

VALI is a general term describing lung damage in UPV. (Some sources rather use the term *VILI - ventilator-induced lung injury* . Definitions vary, somewhere the terms are freely interchanged, elsewhere VILI is considered the "process" and VALI the "result" [10]) This is caused by three main mechanisms: **structural disruption, surfactant dysfunction and “biotrauma”** (damage caused by an inflammatory response). Morphologically, this group includes "classic barotrauma", i.e. the **presence of air outside the alveolar space** (emphysema, pneumothorax, air embolism, ...) as well as other lung damage (**pulmonary edema, alveolar destruction** or the consequences of long-term positive pressure ventilation such as pseudocysts or bronchodysplasia).

The most important prevention of adverse effects of UPV is limiting its duration and decannulation as early as possible. Another way to prevent ENT is to elevate the head, routinely turn the patient, ensure sufficient nutrition with a nasogastric tube or administer prophylactic pharmacotherapy (antithrombotics, H 2 antihistamines).

Termination of artificial pulmonary ventilation, weaning, long-term

UPV

Due to the occurrence of numerous adverse effects of artificial lung ventilation, the effort is to minimize the duration of use. The term ***weaning*** is most often used for this process , thus emphasizing the gradual nature of this process. However, in more recent publications, the term ***discontinuation*** is used more often , i.e. termination, preferring a faster termination of therapy. The appropriate time of stopping UPV is important for the patient's prognosis – stopping too early can lead to muscle fatigue and insufficient respiratory gas exchange (up to the need to resume UPV), on the other hand, stopping too late increases the risks of harm to the patient associated with UPV..[11]

To start weaning, the patient needs to be circulatory stable, show good values of respiratory functions and breathing activity, have preserved airway reflexes and no other conditions that contraindicate termination of therapy (severe anemia, febrile condition) are present. are present. The patient's ability to ventilate spontaneously with minimal or no ventilator support should be checked prior to ventilator disconnection or extubation. Extubation in patients artificially ventilated for less than 24 hours can be performed after 15 minutes of spontaneous ventilation, in patients intubated for longer this interval must be extended. However, it is always necessary to have tools ready for re-intubation and continuation of UPV. The patient must be monitored further after the UPV is completed.

Patients who are indicated for long-term UPV are early **transferred to tracheostomy**.

Links

Related articles

- Securing the airway
- Artificial pulmonary ventilation (neonatology)
- Tracheostomy
- Endotracheal intubation

External links

- Severe respiratory tract infection in a child — interactive algorithm + test (https://www.akutne.cz/algorithm/cs/329--/)
- American Association of Chest Physicians website (http://www.chestnet.org/)
- Learning Portal (https://college.hamilton-medical.com) of Hamilton, a ventilator manufacturer

References

- ŠEVČÍK, Pavel, et al. *Intenzivní medicína.* 3. edition. Galén, 2014. 1195 pp. pp. 368–378. ISBN 978-80-7492-066-0.

Reference

1. HALL, Jesse B – MCSHANE, Pamela J. *Overview of Mechanical Ventilation* [online]. MSD Manual, The last revision 11/2013, [cit. 2018-03-21]. <https://www.msdmanuals.com/professional/critical-care-medicine/respiratory-failure-and-mechanical-ventilation/overview-of-mechanical-ventilation#>.
2. SLUTSKY, A S. Mechanical ventilation. American College of Chest Physicians' Consensus Conference. *Chest* [online]. 1993, vol. 104, no. 6, p. 1833-59, Available from <https://www.ncbi.nlm.nih.gov/pubmed/8252973>. ISSN 0012-3692.
3. BYRD, Ryland P. *Mechanical ventilation* [online]. The last revision 2018-03-20, [cit. 2018-03-22]. <https://emedicine.medscape.com/article/304068-overview#a2>.
4. LEBL, Jan, et al. *Klinická pediatrie.* 2. edition. Galén, 2014. pp. 95. ISBN 978-80-7492-131-5.
5. DORČÁKOVÁ, Kamila. *Nekonvenční umělá plicní ventilace* [online]. [cit. 2018-03-22]. <http://www.kalas.sk/wp-content/uploads/nekonvencna-umela-plicni-ventilace-mrs-dorcakova-cz.pdf>.
6. HYZY,. *High-frequency ventilation in adults* [online]. UpToDate, [cit. 2019-12-27]. <https://www.uptodate.com/contents/high-frequency-ventilation-in-adults>.
7. HYZY, Robert C, et al. *Modes of mechanical ventilation* [online]. UpToDate, The last revision 2019-03-19, [cit. 2020-05-17]. <https://www.uptodate.com/contents/modes-of-mechanical-ventilation>.
8. SAGANA, Rommel, et al. *Positive end-expiratory pressure (PEEP)* [online]. UpToDate, The last revision 2020-01-10, [cit. 2020-05-11]. <https://www.uptodate.com/contents/positive-end-expiratory-pressure-peep>.
9. HESS, Dean R. Recruitment Maneuvers and PEEP Titration. *Respir Care* [online]. 2015, vol. 60, no. 11, p. 1688-704, Available from <http://rc.rcjournal.com/content/60/11/1688,>. ISSN 0020-1324 (print), 1943-3654.
10. HYZY, Robert C. *Ventilator-induced lung injury* [online]. UpToDate, [cit. 2020-05-11]. <https://www.uptodate.com/contents/ventilator-induced-lung-injury>.
11. MACINTYRE, Neil R. The ventilator discontinuation process: an expanding evidence base. *Respir Care* [online]. 2013, vol. 58, no. 6, p. 1074-86, Available from <http://rc.rcjournal.com/lookup/doi/10.4187/respcare.02284>. ISSN 0020-1324 (print), 1943-3654.