Ventilators 101: A Basic Overview

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Introduction: A ventilator, also known as a respirator or breathing machine, is a medical device that provides a patient with oxygen when they are unable to breathe on their own. Mechanical ventilation is the most used short-term life support technique utilized worldwide (Tai et al, 2017).

Mechanical ventilation is utilized in scenarios ranging from planned surgical procedures to acute traumas to acute organ failure (Tai et al., 2017). The following review will assist the Speech Language Pathologist (SLP) to understand the basic physiology and respiratory mechanics of ventilator care.

Physiology of Respiration:

Unassisted Respiration: Respiration is regulated by the medulla oblongata and the pons in the brainstem. The structures involved in breathing include the oral and nasal cavities, larynx, trachea, and lungs (VanDah et al. 2002). The main muscles involved in respiration include the diaphragm and the external and internal intercostals. Also important are the accessory muscles, which include abdominal muscles, the trapezius, pectoralis major, sternocleidomastoid and scalene muscles. These muscles play different roles in inspiration and expiration.

The diaphragm is often considered the most important muscle of respiration. The diaphragm is innervated by the phrenic nerve, which originates in the cervical spine (between C3-C5). The remaining muscles are innervated by nerves in the cervical and thoracic levels of the spinal cord, or cranial nerve XI (accessory nerve). A summary of muscles and corresponding innervation can be found in de Palevill et al., 2011.

Expiration during rest/quiet breathing is largely passive, as expiration occurs when the diaphragm relaxes. Adults have an average resting breath rate of 12-20 breaths per minute (bpm) (VanDahm et al., 2002). Control over respiration changes during speech production, when expiration is more controlled to allow for speaking to occur.

Assisted Respiration: Environmental air contains an average of 21% oxygen (02). Most people are able to maintain adequate oxygenation of their blood at 92-98% oxygenation by breathing room air. People who have respiratory compromise need more support via supplemental oxygen. Remember, the higher the amount of supplemental oxygen a person is receiving, the less stable and efficient their pulmonary status is.

Endotracheal tubes are placed through the mouth to the trachea. They are utilized for short term respiratory management in cases of planned surgical procedures or unplanned medical complications. Should a patient require long term respiratory management, a tracheostomy may be placed.

The length that an endotracheal tube will remain in place is patient dependent, highly variable, and managed by the medical team. Some endotracheal tubes can remain in place for longer than 21 days prior to tracheostomy placement (VanDahm et al., 2002).

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Important Terminology:

Ventilation:
- The process of moving air in and out of the lungs with the most important process being the removal of carbon dioxide (CO_2) from the body (Mora et al., 2018).

Oxygenation:
- Interventions that provide greater oxygen supply to the lungs. In ventilated patients this is achieved by increasing the inspired oxygen (FiO_2%) or the positive end-expiratory pressure (PEEP) (Mora et al., 2018).

Dyspnea:
- Also called shortness of breath (SOB)

Work of breathing (WOB):
- The amount of energy required to inhale and exhale.

Respiratory rate (RR):
- This is the number of breaths per minute spontaneously taken by patient or delivered mechanically by a ventilator.

Positive end-expiratory pressure (PEEP):
- In the mechanically ventilated patient, the positive pressure that will remain in the airways at the end of the respiratory cycle (end of exhalation) that is greater than the atmospheric pressure (Mora et al., 2018). PEEP is used to prevent collapse of alveoli (Vargas et al., 2014)

Peak inspiratory pressure (PIP):
- Highest level of pressure the patient achieves during inspiration. It is different for every breath (VanDahm et al., 2002).

Tidal Volume (TV or Vt):
- Volume of air moved in and out of the lungs in each respiratory cycle (Andres et al., 2018).

Fraction of inspired oxygen (FiO_2):
- Percentage of oxygen in the air mixture that is delivered to the patient (Mora et al., 2018).

Maximum Inspiratory Pressure (MIP):
- How much strength a person has to breathe in. This is assessed by having the patient forcefully inspire as much as they can against an occluded mouthpiece.

Flow:
- Speed in liters per minute at which the ventilator delivers breaths (VanDahm et al., 2002).

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Types of breath a ventilator will provide:

A ventilator provides breath to a patient who can no longer breathe independently. Thinking of ventilation in this capacity simplifies matters. A ventilator will provide three basic types of breaths: a controlled breath, an assisted breath, and a supported or spontaneous breath.

1. Controlled Breath Support:

- This is when the ventilator is in complete control of breath support. Your patient will expend no effort during respiration because the ventilator will do everything. The ventilator will provide a consistent amount of oxygen at a consistent time to the patient (eg: a breath every 5 seconds with the same quantity of oxygen delivered). Consider a chemically or physically paralyzed person – they would need these types of breaths. On vent modes with this setting the patient would NOT be able to take any spontaneous breaths, so use of these settings is limited. (Mora et al., 2018)

2. Assisted Breath Support:

- This breath support is partially controlled by the ventilator. This means that if the person is spontaneously trying to take a breath the vent will let them, but if they do not take a breath in time, the vent will provide them one. Essentially, with assisted breath support, the person can initiate breathing if they are able to, but if they fail to initiate a breath in time, the ventilator will take over and breathe for them. (Mora et al., 2018)

3. Supported or Spontaneous Breath Support:

- This is when breathing is triggered completely by the patient, but once the breath is triggered, the ventilator will provide some very minimal oxygen and pressure support. (Mora et al., 2018)

Tracheostomy with Ventilation:

If your patient is intubated for a prolonged period of time and cannot be liberated from ventilator support, the medical team may wish to pursue placement of a tracheostomy. Below is a brief review of the components of a tracheostomy. For further information on the components of a tracheostomy, refer to the Trachestomy 101 handout.

Outer cannula:

- This is the outer tube that helps maintain the patency of the stoma (the opening made in the neck by the tracheostomy)

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Inner cannula:

- This is a tube that fits inside the outer cannula and can be removed and replaced or cleaned after secretions build up inside it.
- The inner cannula may be "fenestrated" or have holes in it. It was once thought that a fenestrated trach helped with speaking valve toleration, but this type of trach is a high risk for granulated tissue formation and can make it more difficult to ventilate a patient.

Hub:

- This is the prominent end of the inner cannula that is the point of connection between the tracheostomy tube and ventilator tubing or a speaking valve

Cuff:

- This is an inflatable and deflatable balloon that surrounds the trach tube. It is used to seal the airway preventing air from escaping from the lungs and will typically be inflated while patient is on vent support.

Pilot Balloon

- This is a plastic balloon connected by thin plastic tubing attached to the trach. This allows medical staff to determine if the cuff is inflated or deflated.

Obturator:

- This is the guide used during tracheostomy placement. After placement it is typically sterilized and saved in the event of the trach accidently gets removed and needs to be replaced.

It is important to note that there are some single cannula tracheostomies on the market. A physician will make the decision on the type of trach used for a patient.

References:

de Paleville, D. G. T., McKay, W. B., Folz, R. J., & Ovechkin, A. V. (2011). Respiratory motor control disrupted by spinal cord injury: mechanisms, evaluation, and restoration. Translational stroke research, 2(4), 463-473.

Kallet, R.H., Campbell, A.R., Alonso, J.A., Morabito, D.J., Mackersie, R.C. (2000). "The effects of pressure control versus volume control assisted ventilation on patient work of breathing in acute lung injury and acute respiratory distress syndrome". Respir Care. 45(9): 1085–96.

Mora Carpio AL, Mora JI. Ventilator Management. [Updated 2018 Nov 23]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2018 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK448186/

Pham, T., Laurent, B.J., Slutksy, A.S. (2017). Mechanical Ventilation: State of the Art [Abstract]. Mayo Clinic Proceedings, 92(9), 1382-1400.

VanDahm, K., & Sparks-Walsh, S., (2002). Tracheostomy tubes and ventilator dependence in adults and children: A handbook for the speech-language pathologist. Austin, Tx: Pro-Ed.

Vargas, M., Sutherasan, Y., Gregoretti, C., & Pelosi, P. (2014). PEEP role in ICU and operating room: from pathophysiology to clinical practice. The Scientific World Journal, http://dx.doi.org/10.1155/2014/852356

Wilcox, S. R., Aydin, A., & Marcolini, E. G. (2018). Modes of Invasive Mechanical Ventilation. Mechanical Ventilation in Emergency Medicine, 43-52. doi:10.1007/978-3-319-98410-0_5

Yonis, H., Crognier, L., Conil, J., Serres, I., Rouget, A., Virtos, M., et al. (2015). Patient-ventilator synchrony in Neurally Adjusted Ventilatory Assist (NAVA) and Pressure Support Ventilation (PSV). BMC Anesthesiol. 8;15:117.