# Non- Invasive Home Ventilation & Mechanical In-exsufflation

This learning module is intended as a review of foundational knowledge for practitioners in the community working with children and their family who require non-invasive ventilation support or mechanical in-exsufflation. In order for the associated workshop to be effective it is recommended this module be completed prior to the session.

*2020*

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# Contents



## Learning Outcomes

- ✓ Outline key differences in the paediatric respiratory system
- ✓ Identify indications for mechanical ventilation
- ✓ Describe common modes of ventilation used in paediatrics
- ✓ Summarize key factors when caring for a child receiving ventilation support
- ✓ Describe mechanical in-exsufflation therapy and indications for use
- ✓ Identify appropriate strategies for alarm management

## Recommended Resources

*Stellar 150 Video*: https://vta.allego.com/home.do?folderId=1327

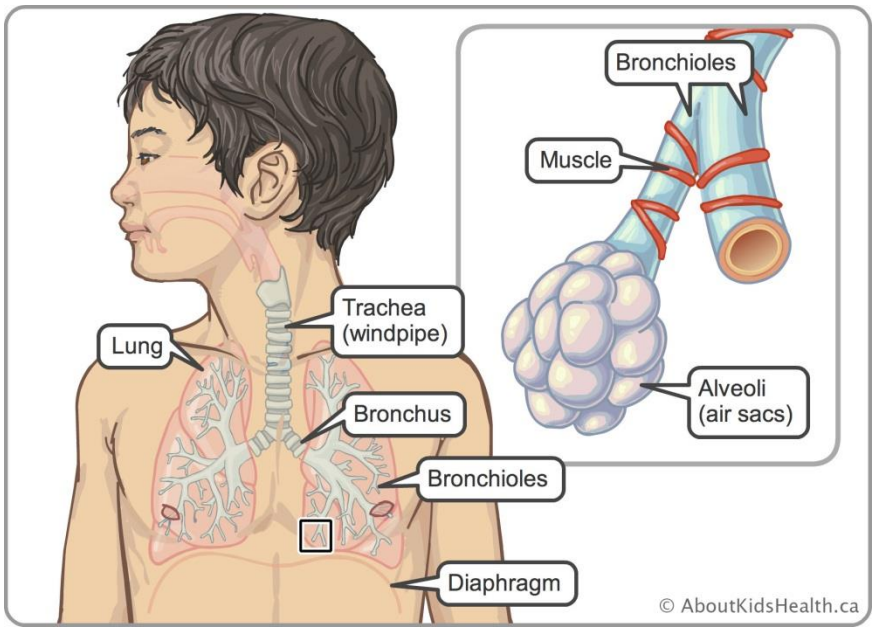
**Ventilator Equipment Pool Video Resources** http://ontvep.ca/videos/
*How to set up your Stellar 150*
*Stellar 150 Learned Circuit Guide*
*Stellar 150 Humidifier Cleaning Guide*

# The Paediatric Respiratory System

Understanding how a child breathes is an important part of learning how to care for your child's tracheostomy.

A child's respiratory system can be broken down into the:

- upper respiratory tract
- lower respiratory tract




## Anatomy

### Upper respiratory tract

**Nasal cavity**
Air is warmed, moisturized and cleaned. Tiny hairs called **cilia** line the inside of the nose and filter the air.

**Oral cavity**
Air is warmed and moisturized however, there are no cilia in the oral cavity, so the air is **not** filtered.

**Pharynx**
The **pharynx** is a muscular tube between the nose and the mouth.

**Larynx (voice box)**
The larynx (voice box) is between the pharynx and the trachea. It contains the vocal cords. When air is breathed in and out, voice sounds are created here. *The vocal cords* can be closed to build up pressure in the lungs and create a strong cough.

**Epiglottis**
The epiglottis is a flap that hangs over the larynx. When you swallow, this flap covers the larynx so food and/or drink will go into the esophagus and not into the trachea and lungs.

**Esophagus**
The esophagus is the feeding tube that connects the pharynx and the stomach.

## Lower Respiratory Tract

**Lungs**
The lungs are the two organs used for breathing in the body. The lungs take in oxygen from the air and release carbon dioxide.
**Trachea**
The trachea is the breathing tube that connects the larynx to the lungs. This is where a tracheostomy tube is inserted.
**Bronchi and bronchioles**
The trachea divides into two hollow tubes called bronchi, which supply air to each lung. The bronchi divide into smaller and smaller hollow tubes called bronchioles. These are the smallest air tubes in the lungs.
**Alveoli**
The alveoli are tiny sac-like structures at the tip of the bronchioles. They allow oxygen and carbon dioxide to move in and out of the lungs.
**Pleura**
The *pleura* are membranes that surround the lungs. The *parietal pleura* is the outside membrane. The *visceral pleura* is the inside membrane, attached to the lungs.
**Capillaries**
The capillaries are blood vessels in the walls of the *alveoli*. Blood flows through the capillaries, removing carbon dioxide and picking up oxygen.

## Respiratory Muscles

**Diaphragm**
The diaphragm is a large, sheet-like muscle. The diaphragm is the main muscle involved in breathing. It is always active.
**Neck muscles**
If a child is having difficulty breathing, the muscles of the neck can help.
**Intercostal muscles**
The intercostal muscles are the muscles between the ribs.
**Abdominal muscles**
The abdominal muscles help move air in and out of the lungs. They also help to create a good strong cough.

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# Respiratory Distress in Children

When a child is having difficulty breathing (respiratory distress), you may see one or more of the following signs.

**Early signs of respiratory distress**

- Coughing
- Abnormal breathing sounds such as wheezing
- Anxiety or restlessness in your child that cannot be calmed with normal comforting
- Faster heart rate or breathing than normal
- Fever

If the child has an increased heart rate or breathing, try to calm them down and see if their heart rate and breathing rate return to normal.

**Late signs of respiratory distress**

- ✓ "Rattling" in the child's chest or back
- ✓ Obvious distress or agitation
- ✓ Retractions
- ✓ Nasal flaring
- ✓ Tripod position (sitting or standing while leaning forward and supporting the upper body with hands on the knees or on another surface)
- ✓ Cyanosis
- ✓ Sleepiness or unresponsiveness

If there is a "rattling" sound when the child breathes, encourage them to try to cough up the mucus to clear their lungs. Cyanosis indicates that the child is not getting enough oxygen. Unresponsiveness indicates that the child has a high level of carbon dioxide in their lungs.

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# Mechanical Ventilation

Some children may need a ventilator to assist with moving air in and out of their lungs because they are unable to do this on their own. A ventilator can do all of the breathing (total support) or some of the breathing (partial support). Many ventilators can provide extra pressure (e.g. PEEP pressure) to prevent the air sacs in the lungs from collapsing.

## Indications for Ventilation

Certain lung, heart, neurological or muscle diseases can make breathing more difficult.

Mechanical ventilators are used when:

- The brain cannot send signals to the lungs to breathe
- The lungs are too stiff to expand fully
- The lung tissue is damaged
- Muscles for breathing are not strong enough to move air in and out of the lungs
- The heart has been damaged and causes the lungs to work very hard

## Types of Ventilation

Ventilators offer a wide variety of modes that determine how and when a breath is delivered to a child. The mode of ventilation is carefully assessed for each child and could change as the child's condition changes.

### *Volume Ventilation*

This mode of ventilation requires giving a set amount or set volume of air to the lungs.

### *Pressure Control Ventilation*

This mode of ventilation refers to the flow of air to the lungs. The ventilator uses as much flow needed to inflate the lungs to the pressure that is set on the machine. This is the preferred mode in children.

## Types of Breaths Delivered by the Ventilator

### Spontaneous

A spontaneous breath is triggered by the child. Breaths are initiated by the child's inhalation effort, and air delivery is controlled based on the current pressure or volume setting. Breaths are terminated by either the ventilator settings or by the child's exhalation effort, depending on the mode selected.

### Mandatory

A mandatory breath (or mechanical breath) is completely controlled by the ventilator. The ventilator controls both the beginning (triggering) and end (cycling) of the inspiratory phase of breathing. The breaths are delivered based on how the pressure or volume is set.

### Assisted

An assisted breath is controlled by both the child and the ventilator. Breaths are initiated by the child's effort and air delivery is controlled by the current pressure or volume settings. Volume assisted breaths will deliver the prescribed tidal volume within the prescribed inspiratory time. Pressure assisted breaths will deliver the prescribed inspiratory pressure for the prescribed inspiratory time. Breaths are terminated when the inspiratory time setting has been reached.

## Modes of Ventilation

Common ventilator modes in paediatrics:

| Mode | Function |
|---|---|
| **Assist/Control (A/C)** | Ventilator is set up to deliver a certain number of breaths to the child in a minute |
| **Synchronized Mandatory Intermittent Ventilation (SIMV)** | Ventilator senses when the child is making the effort to breathe. It allows for spontaneous breaths between mandatory breaths |
| **Continuous Positive Airway Pressure (CPAP)** | Ventilator delivers no mandatory breaths. The ventilator will deliver as much flow and volume as the child demands when they breath in |
| **Pressure Support (PS)** | Ventilator delivers a set pressure when the child breathes a breath on their own |
| **Pressure Control (PC)** | Ventilator is set to the highest pressure to be delivered during a breath. The pressure is held for the duration of inhalation |
| **Spontaneous/Timed Out (S/T)** | Provides spontaneous and mandatory (timed) breaths. A mandatory breath is delivered if the child does not spontaneously breathe within a prescribed breath rate setting |
| **Control Ventilation (CV)** | Ventilator delivers volume control therapy. A mandatory breath with a set volume is delivered to the patient |

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# Non-invasive Positive Pressure Ventilation

One type of non-invasive positive pressure ventilation (NPPV) is Bi-level Positive Airway Pressure (Bi-level) therapy. A BiPAP machine delivers pressurized air through a mask.

### Indications for Bi-level Therapy

- Carbon dioxide ($CO_2$) levels are high during the day and/or night
- Child has pauses in breathing during sleep with no breathing effort (central sleep apnea)
- Continuous Positive Airway Pressure (CPAP) does not work
- Weak breathing muscles (e.g. Spinal Muscular Atrophy)
- Lung Disease (e.g. Cystic Fibrosis)
- Scoliosis
- Obesity
- Congenital Central Hypoventilation Syndrome (CCHS)
- Down syndrome

### Benefits of Bi-Level Therapy

- Improves quality of sleep and quality of life
- Prevents hospital admissions

Bi-level therapy will not prevent the progression of the underlying disease or prevent a child from getting sick (it may decrease how sick a child gets with an infection)

## Bi-Level Settings

Bi-level settings are determined during a sleep study and/or a hospital admission. They are adjusted according to the child's comfort, oxygen and carbon dioxide levels
The following table outlines Bi-level settings:

| SETTING | FUNCTION |
|---|---|
| **Spontaneous (S) Mode** | The child starts all breaths |
| **Spontaneous/Timed (S/T) Mode** | The child starts each breath and the machine delivers a breath only if the child's breath rate falls below the set machine rate |
| **Volume Assured Pressure Support (VAPS)** | The pressure to be delivered is automatically adjusted by the machine to make sure the same volume is always given |
| **Inspiratory Positive Airway Pressure (IPAP)** | This pressure inflates the lungs when the child breathes in |
| **Expiratory Positive Airway Pressure (EPAP)** | This pressure prevents the airway from closing when you/your child is breathing out |
| **Back-up Rate** | The number of breaths delivered by the machine in one minute if the child's breathing rate falls below the rate set on the machine |

| | |
|---|---|
| **Inspiratory Time** | The time in seconds during which the child will receive the IPAP |
| **Rise Time** | The time taken for the pressure to reach the IPAP from the EPAP |
| **Ramp** | The number of minutes that the machine takes to reach the set pressures |

## Types of Masks

Nasal
- Fits over the nose
- Most commonly used

Oronasal (Full Face)
- Covers both the nose and the mouth
- Used if there is significant air leak with nasal masks

Total Face
- Covers the eyes, nose, and mouth

Nasal Pillows
- Inserts directly into the nose
- Good option for teenagers
- Often too big for younger children

## Alarms

The following table outlines common alarms and troubleshooting strategies:

| ALARM | POSSIBLE CAUSE | WHAT TO DO |
|---|---|---|
| **Low Pressure** | The Bi-level machine does not reach the pressure needed to give a full breath | Check for leaks/cracks in the tubing or around the mask |
| **High Pressure** | The Bi-level machine reaches a high-pressure cut-off | The airway may be blocked and the child may need to be suctioned. Other causes include a kink or water in the tubing or blocked exhalation port |
| **High Leak** | High mask leak for more than 20 seconds | Adjust the mask to minimize leak |
| **Low Minute Ventilation** | Minute ventilation has dropped below the alarm setting level | Reassess the child to ensure adequate therapy |

| | | |
|---|---|---|
| **Non-vented Mask Alarm** | A non-vented mask may be connected or mask vents may be blocked | Ensure the mask has vents and ensure the mask vents are not blocked |
| **Low Respiratory Rate** | The respiratory rate has dropped below the alarm setting level | Reassess the child to ensure adequate therapy and ensure the alarm setting is appropriate for the child |
| **High Respiratory Rate** | The respiratory rate has exceeded the preset alarm level | Reassess the child to ensure adequate therapy and ensure the alarm setting is appropriate for the child |
| **Internal Battery Low** | The internal battery capacity is below 30% | Connect the device to the main power |
| **System Failure** | Component failure<br>The device stops delivering air pressure<br>Therapy cannot be started | Power off the device<br>Call for replacement |

## Common Complaints

The following problems may arise with Bi-level therapy:

Child will not wear the mask

- ✓ Make it fun. Put the mask on the entire family
- ✓ Start with wearing the mask during the day working up to 30 minutes continuously
- ✓ Slowly increase the number of minutes per day the child wears the mask.

The mask is not comfortable

- ✓ Check the mask fit
- ✓ Make sure the headgear is not too tight. Two fingers should be able to slip between the strap and the child's head

The skin on the forehead, nose or cheeks is red in the morning

- ✓ Check the mask fit
- ✓ Consider a new mask that does not apply pressure in the same spots
- ✓ Make sure the headgear is not too tight.
- ✓ Consider the use of gel pads or liners that fit underneath the mask

Sore eyes in the morning

- ✓ Check the mask fit
- ✓ Inquire about the use of eye drops

Nosebleeds and nasal congestion

- ✓ The air delivered by the machine is not carrying enough moisture (i.e. water)
- ✓ Consider using the humidifier

- ✓ If the humidifier is being used and the child's nose still feels dry or is bleeding check the humidifier setting and check with the healthcare team to see if the setting can be increased
- ✓ Consider discussing with the healthcare team about a prescription for nasal steroids

Headaches in the morning

- ✓ Ensure the exhalation port on the mask is not being blocked by the bed covers. If there is an exhalation flap in the mask, make sure it is not sticking
- ✓ May be due to an increase in carbon dioxide levels in the blood. If this is the case, the health care team will need to be notified

Gagging or vomiting in the morning

- ✓ If this happens a discussion with the child's health care team may be required
- ✓ These symptoms may indicate the following:
- ✓ Need to increase the gastroesophageal reflux medications
- ✓ Need to vent the G-tube if the child has one
- ✓ Need to decrease the IPAP and EPAP (MD/NP orders)
- ✓ Stop overnight feeds or decrease the volume of feeds
- ✓ Stop eating (by mouth) 1 hour before Bi-level therapy
- ✓ Avoid use of an oronasal or total face mask

# Pulmonary Clearance

A strong cough is important to remove *mucous* from the lungs.

There are two considerations for a strong cough:

- ✓ The child's ability to take a big breath in to completely fill lungs with air
- ✓ The child's ability to breathe out forcefully

In order for the child to have a strong cough, the following needs to be present:

- An inhalation (i.e. taking a big breath in)
- A forced exhalation (i.e. breathing out forcefully) with the glottis closed. The glottis is in the area where the vocal cords are located; it is the middle part of the larynx. Muscles are used to close the glottis.
- An explosive release of air when the glottis opens.

If the child's breathing muscles are weak, the cough will be weak too. There are exercises and devices that can be used to help strengthen the child's cough to help clear the mucous from their lungs.

### What is Pulmonary Clearance?

Pulmonary Clearance techniques are exercises and devices that can be used to help the child cough.

If these exercises are used daily, the child will be able to move the *mucous* up from the airway into their tracheostomy, throat or mouth, where it can be suctioned out.

What are the benefits of Pulmonary Clearance Techniques?

- ✓ May improve the amount of air your child can breathe into and out of the lungs
- ✓ May improve coughing and speaking
- ✓ May improve the amount of *oxygen* getting to the body
- ✓ May prevent the air sacs from collapsing
- ✓ May prevent lung infections

## Introduction to Mechanical In-Exsufflation

Mechanical in-exsufflation (e.g. Cough Assist) helps children have a stronger cough to assist with clearing secretions from the lungs. This machine delivers pressurized air when the child breathes in. It is then followed by a rapid switch to a negative pressure to suck the air out of the lungs which causes the child to cough.

Indications for this type of therapy include:

- ✓ Children with a weak cough who are unable to perform lung volume recruitment
- ✓ Children who have difficulty with secretion clearance
- ✓ Children who have lung collapse caused by mucous plugging

Contraindications for this type of therapy include:

- ✓ A history of bullous emphysema
- ✓ Susceptibility to pneumothorax or pneumo-mediastinum
- ✓ Any recent barotrauma
- ✓ Untreated tension pneumothorax
- ✓ Active bleeding in the lungs
- ✓ Suspected or confirmed head and/or c-spine injury
- ✓ Unrepaired tracheoesophageal fistula
- ✓ Certain heart conditions (e.g. Fontan)
- ✓ Burns, open wound, infection or skin grafts on the thorax
- ✓ Recently placed transvenous pacemaker or subcutaneous pacemaker
- ✓ Suspected pulmonary tuberculosis
- ✓ Select airway anomalies such as tracheobronchomalacia
- ✓ Recent lobectomy/pneumonectomy
- ✓ Severe obstructive lung disease (e.g. severe asthma)

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