Invasive Ventilation with a Tracheostomy

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

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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
- ✓ Identify appropriate strategies for alarm management

Required Videos

Log into Connected Care Live to access the video library for invasive ventilation. If you are not registered with Connected Care Live you can register on the site:
https://www.connectedcare.sickkids.ca/connected-care-live

Video Resources on Connected Care Live - https://skconnectedcare.zendesk.com/hc/en-us/categories/360002870652-Home-Ventilation-Invasive-Non-Invasive-

Supplemental Resource

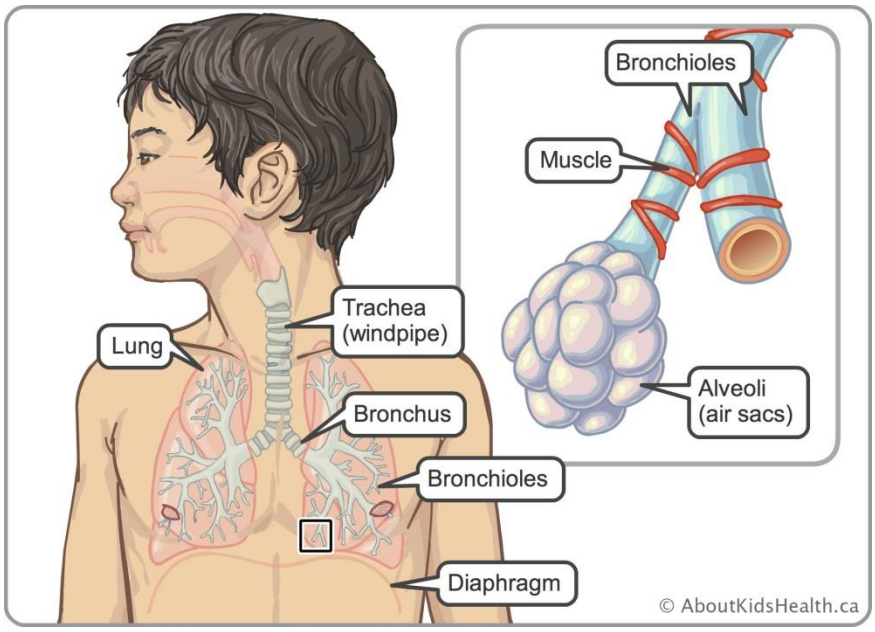
AboutKidsHealth. (n.d). *Tracheostomy and ventilation manual for family caregivers*.
https://www.aboutkidshealth.ca/trachvent

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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Ventilator Settings

The following are general ventilator settings that are common in most home ventilators.
Please refer to your ventilator manual for the specifics of the ventilator that you are using.

Setting	Function
BREATH RATE/RESPIRATORY RATE	Sets the number of machine breaths to be delivered to the child in one minute
TIDAL VOLUME	Selects the volume of air to be delivered during the volume controlled breaths
INSPIRATORY TIME	Selects the length of time the breath is held in the inspiratory phase (breathing in) during volume control or pressure controlled machine breaths
INSPIRATORY FLOW RATE	How fast the air travels during one breath
SENSITIVITY	Adjusts the amount of effort the child needs to make in order to trigger the ventilator to deliver a machine breath or assist spontaneous breaths
MINUTE VENTILATION	Amount of ventilation that is delivered to the child's lungs over the last minute. It is a calculation of tidal volume and respiratory rate
I:E RATIO (Inspiratory to Expiratory Ratio)	Length of time it takes to breathe in compared to the time it takes to breath out
PEAK INSPRIATORY PRESSURE (PIP)	Amount of pressure it takes to fill up the lungs with the child breathes in
POSITIVE END EXPIRATORY PRESSURE (PEEP)	Pressure the ventilator holds at the end of each breath. This helps to keep the air sacs open to they do not collapse

Machine Settings	
Setting	**Function**
START/STOP BUTTON	Turns the ventilator airflow on or off
ALARM INDICATOR AND AUDIO PAUSE BUTTON	Indicates an alarm condition by flashing or producing a light. The audio pause button is often the same button pushed to silence the audible alarm for a designated period of time
NAVIGATION BUTTONS	These are usually displayed as UP/DOWN or LEFT/RIGHT button for when you have to navigate through settings on the screen
VISUAL INDICATORS	Usually red, yellow or green LED indicator lights used for a variety of reasons: • Power LED's • Keypad backlights • Alarm LED's

AC POWER INLET	Ability to plug the AC power cord into the ventilator
EXTERNAL BATTERY CONNECTION	Most portable ventilators offer an option to connect an external battery for long term power requirements such as a power failure or for travel
AIR INLET	This is where the air enters the ventilator. The air must pass through an inlet filter to reduce environmental particles and bacteria into the child's lungs
OXYGEN INLET CONNECTOR	If supplemental oxygen is prescribed, this is where it is added into the ventilator
BREATHING CIRCUIT CONNECTION	Air exits the ventilator and goes into the attached breathing circuit
SD CARD OR USB SLOT	Most new ventilators have the option of upload patient data so that your healthcare tem can record usage and therapy information
DISPLAY SCREEN	Allows the ability to view settings, system status information, real-time patient data, alarms, and logs. Modifications to certain settings can be done on the display screen

Power Supply

Ventilators need electricity to operate. There are three sources of electricity that are available to run the ventilator: A/C, External D/C and Internal D/C.

Alternating Current (A/C) – This power source is used most of the time. It is when the ventilator will be plugged into a home wall outlet. This power source has 120 volts of alternating current (A/C).

External (Direct Current) D/C battery – This is the extra battery provided with the ventilator. It is used if a power failure were to last longer than 30-60 minutes. This battery is a standard 12 volt battery. It would provide power to the ventilator for 8-24 hrs depending how much the battery has been used and the patient's ventilator settings demand.

Internal battery - This is the battery built inside the ventilator. It used for short term power. It can power the ventilator for 2-3 hours if it is fully charged. It will need to be discharged and recharged every month.

The Ventilator Circuit

The ventilator circuit is what connects the ventilator to the tracheostomy tube. There may be differences between ventilator circuits used with each child. The following components are present in a circuit:

- **Outlet filter** – filters gas coming from the ventilator, going into the circuit tubing
- **Ventilator circuit tubing** – six foot hose that attaches to the exhalation port and outlet port
- **Exhalation valve (active)**– a balloon that closes when the child breathes in and opens when the child breathes out. The flex tube attaches to one end and the ventilator circuit tubing to the other end**.**
- **Exhalation valve (passive) -** a connector with holes to allow for exhaled gases to escape.
- **Exhalation valve line** – connected to the exhalation valve and exhalation valve port on the ventilator
- **Pressure line (in active circuit type)** – small tube that is connected to two pressure ports (one on ventilator and other on exhalation valve)
- **Tracheostomy connector** – attaches the ventilator circuit tubing to the tracheostomy tube.

Cleaning the Circuit

The ventilator circuit, resuscitation bag, humidifier and suction canister should be cleaned at least once a week.

Supplies:
Mild dishwashing soap
Two Pails/Buckets
White Vinegar
Clean Towel
Storage Bag

Procedure:

1. Take apart all tubing and connectors (including heated wire in tubing and humidifier jar if used). Immerse tubing, connectors, pressure sensing lines and exhalation line into solution carefully. Water that collects inside the pressure sensing and exhalation tubes can be removed by using a syringe to force it out.
2. Wash in warm soapy water in pail #1.
3. Rinse with tap water to remove soapy residue
4. Submerge all tubing and connectors (including humidifier jar) in pail #2 a solution of one part vinegar and three parts water for 30 minutes. Ensure that everything is filled with the vinegar solution during the soak. Rinse well and shake off excess water as much as possible. Place on clean towel to dry or hang to dry.
5. Wipe down any wires (heated wire, temperature probe, humidifier wires).
6. Reassemble all tubing as instructed, visually inspecting for cracks or tears.
7. When not in use, keep clean circuit in clean bag or storage container.

Alarm Management

The following table outlines common high priority alarms, possible causes and troubleshooting strategies:

ALARM	POSSIBLE CAUSES	WHAT TO DO	OTHER
Circuit Disconnect	• Breathing circuit disconnected • Large leak	• Re-attach breathing circuit • Check for any leaks	Recommended settings: Infants: 5-10 secs Peds: 5-20 secs Adults: 10-60 secs
Low Exhaled Tidal Volume (Vte)	• When patient's exhaled tidal volume falls below what is set	• Check for any leaks (e.g. patient, circuit, humidifier, connections) • Check for airway occlusion and suction patient as needed	
Low Minute Volume (MV, MinVent, MMV, Ve)	• When patient's minute ventilation falls below set minute ventilation • Disconnection of ventilator circuit from child's tracheostomy or leak around tracheostomy • Leaks in the ventilator circuit • Alarm set incorrectly • Change in child's medical status	• Look for any leaks • Reconnect child to ventilator • Examine exhalation valve • Reevaluate child. Contact physician or hospital	Important: Due to the high flow resistance of tracheal tube connectors used in pediatrics, a disconnect of the tracheal tube from its connector may go undetected. Also, a pediatric trach may develop enough back pressure during a partial decannulation (e.g. when moving a patient) to prevent detection of the disconnection from the ventilator.
High Respiratory Rate (RR)	• Total respiratory rate is greater than what is set for the high RR setting	• Check the patient for any respiratory distress, need for suctioning or tracheal tube change, water in the tubing\ • Check for condensation build-up ("water") in the tubing • Check for leaks – where? Patient's	

		trach, tubing, connectors, humidifier	
Loss of Power	• Complete loss of power (no therapy) • Internal battery is discharged	• Operate ventilator on AC Power or other alternate power source	
Low Circuit Leak	• Leak in the circuit	• Ensure exhalation device is connected properly and functioning • If using a nebulizer, ensure you have taken it out of line after a treatment	• Built in leak • Only occurs in passive circuit
Check Circuit	• Occurs when the ventilator detects a problem with the patient circuit or with the active exhalation device (in the 'active' type of circuit)	• Look for a pinched/kinked tube • Ensure no condensation in tubing • If Active Flow Circuit, ensure the exhalation device's diaphragm is moving and not stuck because of condensation • Make sure all tubing is attached in the correct order	
Ventilator Inop Alarm	• Occurs when the ventilator detects an internal error or condition that might affect therapy	• The device will shut down if it cannot deliver therapy safely • Place patient on back up ventilator	

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