

Respiratory Changes After SCI

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This page provides an overview of how spinal cord injury (SCI) affects breathing and coughing, and the acute treatments used to address these issues.

Key Points

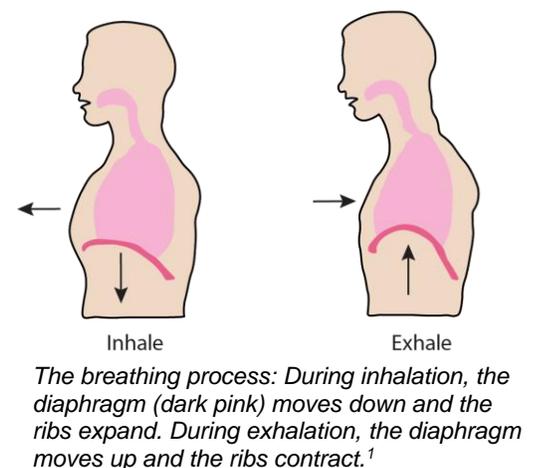
- Spinal cord injury can damage the muscles of breathing, affecting the ability to take a deep breath, cough and clear mucus, and maintain adequate oxygen levels. The extent of these changes depends on the level and completeness of the SCI with higher cervical injuries being more affected.
- A wide range of management options may be used to assist or improve the effectiveness of breathing and coughing in acute and chronic SCI, including tracheostomy and intubation in severe cases, non-invasive ventilation, along with assisted coughing techniques.
- A number of secondary respiratory complications can affect people with SCI long after injury, including lung infections like pneumonia.
- Preventative strategies such as flu shots, smoking cessation, and healthy living are an important component of respiratory care.

How does the respiratory system work?

The respiratory system is responsible for helping you breathe in (inhaling) and out (exhaling). Breathing is done through the nose and mouth, although the nose is more often used. One reason the nose is used more often is because it acts as a filter for debris, which protects the lungs. Coughing is another important part of the respiratory system, as it helps to clear mucus from your lungs and airways.

Many muscles help with respiratory functions. The muscles used for inhaling are controlled from the spinal nerves of the neck (C3-C5 primarily), with some help from the nerves of the lower neck and thorax (C6-T12). Inhaling is mostly facilitated by your *diaphragm*, which is a large dome shaped muscle underneath the lungs. When you breathe in, your diaphragm lowers and the space in your chest increases, pulling air into the lungs. When you exhale, your ribs move back in and the diaphragm moves back up.

Breathing during exercise and coughing requires extra effort. To help, the *abdominal muscles* (over your belly) and the *intercostal muscles* (which help to squeeze the ribs) are activated, allowing for a stronger inhalation and a forceful cough.



How does an SCI affect the respiratory system?

When someone is unable to breathe or cough by themselves, their function, independence, and health are affected. These respiratory complications arise in 36-83% of individuals after SCI. This is due to disruption of the breathing nerves after an injury, and to secondary complications of an SCI, such as spasticity. After an SCI, breathing muscles may be partially or completely affected, depending on the completeness of the injury. However, breathing ability may improve over time.

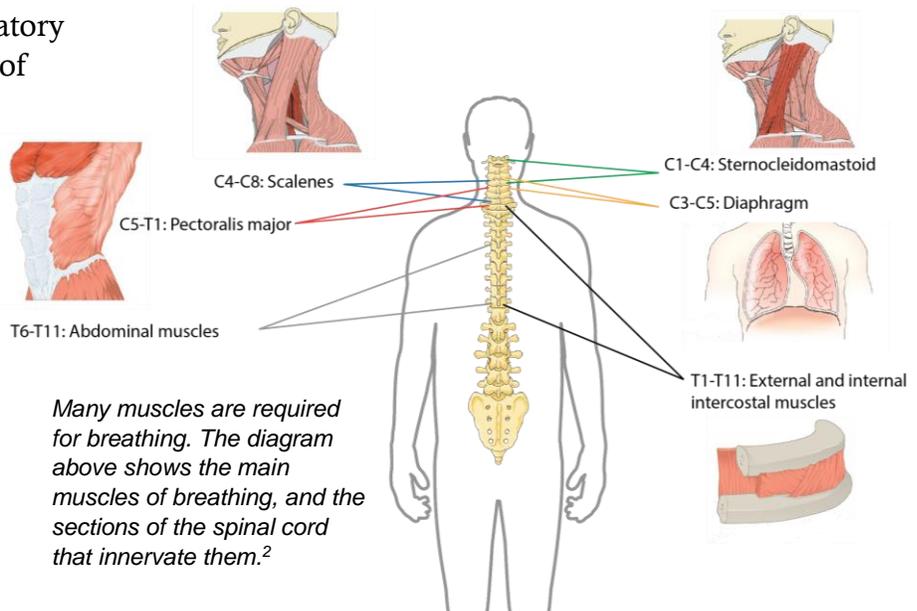
Refer to our page on [Evidence](#) for more information on conflicting evidence.



The chances of experiencing respiratory complications depend on a variety of factors, including:

- The level of injury (dictates which muscles are spared)
- The completeness of an injury
- Timing of a tracheostomy*
- The cause of injury
- Age*

* Conflicting evidence



Changes in breathing

Changes in amount of air getting into the lungs

After injury, the amount of air that can be inhaled and exhaled are significantly reduced for people with cervical and higher thoracic (neck and upper back) level injuries. More specifically, the amount of air that can fill the lungs (known as the *total lung capacity*) is reduced to 60-80% of normal values. Additionally, the amount of air that can be exhaled after the biggest breath in (known as the *vital capacity*) is reduced to 50-80% of normal values. This contributes to inefficient breathing that may be tiresome and difficult. In addition, a lower vital capacity can impact voice volume, making it difficult to speak at louder volumes.

Changes to the lung

An SCI can affect the lung itself. The main change is a reduction in *lung compliance*, or the lung's ability to stretch and expand. As a result, the lung does not spring back "closed" after being open. In addition, the compliance of the rib cage (chest wall) may also decrease, causing the chest to become rigid in individuals with tetraplegia. Reduced compliance results in a decreased ability to take a deep breath independently or with the help of a breathing bag or ventilator.

Changes in coughing

Coughing is important to keep the airway and lungs clear from mucus. This is because a build up of mucus can collapse the lungs, and mucus in the airways can result in infection. In order to perform a

cough, one needs to inhale deeply then have a forceful exhale while a structure called the *glottis* closes the entrance to the windpipe. The intercostal muscles and the abdominal muscles assist with the ability to increase the force of exhaled air. As these muscles are innervated by nerves in the chest region, individuals with spinal cord injuries may have an impaired coughing function. Cough function may be completely absent in some individuals, while others may have limited or ineffective coughing abilities.

Changes in lung irritability and mucous production

Soon after injury, it is common for individuals with high-level SCI to produce a lot of mucus in their lungs and have smaller airways deep in the lung. The lungs are also very irritable to stimuli like too much suctioning of mucus, or smoking. This may be due to the increased influence of the *parasympathetic nervous system* after SCI. In people with acute tetraplegia, it has been reported that an excess of up to 1 liter of mucus is produced each day. In combination with an inability to cough, this excess production of mucus can result in a buildup of fluid in the lungs and airway.

Changes in swallowing

Although swallowing is important for eating, it is also important for clearing the throat to prevent food, drink, stomach contents, or saliva from entering the lungs (also known as *aspiration*). After SCI, the risk of aspiration increases as:

- Your ability to cough may be limited by medical conditions and weakness due to your injury
- Surgical procedures on the spine may compress your throat
- You may feel less alert due to sedative medications
- Some medications you may be on can lead to dry mouth
- Your sensation may be impaired, which prevents you from feeling food or liquid in the spaces at the back of your throat

The lack of effective swallowing can cause mucus to collect in your airway. Over time, the stagnant mucus can encourage the growth of bacteria, which may travel down to your lungs and potentially result in pneumonia.

How can respiratory complications be managed acutely?

Secretion Removal Techniques

Efficient removal of mucus from the airways is important to prevent choking and lung infections, especially when independent coughing is difficult. Although research on the topic of secretion removal techniques is scarce, one study with moderate evidence showed that manual removal techniques combined with mechanical removal techniques are effective in SCI early after injury. Different techniques are outlined below:

Postural drainage

Certain body positions can use gravity to drain mucus towards the throat to be excreted easier. For example, laying on your side with your feet elevated can help drain the lower lung. In order for these positions to be effective, your body must be positioned in specific angles. Refer to your

healthcare professional for more information. To facilitate breakup and movement of the mucus buildup in the lungs, postural drainage can be paired with applying pressure to the chest (*chest percussion*) or shaking the chest (vibration).

Manual assisted coughing

Physical pressure is applied to the chest or abdomen right before expiration to help the individual breathe out. This can be done on yourself or by a trained family member or caregiver.

Mechanically assisted coughing (insufflation-exsufflation)

There are machines that help loosen secretions, clear mucus, and can trigger a cough. They work by delivering a deep breath by pushing air into the lungs, then facilitate exhalation by sucking the air out.

Suction

A tube can be inserted through the mouth or tracheostomy site to suction mucus that is stuck in the upper airways. Suctioning may also reflexively trigger a cough.

Respiratory Muscle Training

Weak inspiratory muscles can result in breathlessness. Like exercise training, inspiratory muscle strength and endurance can increase with training and decrease bouts of shortness of breath (*dyspnea*) and coughing. Inspiratory muscle training involves using devices that create resistance when breathing in.

Refer to our article on [Inspiratory Muscle Training](#) for more information!



Resistive trainers have adjustable settings that allow individualized training programs.³

Drug Treatments

Bronchodilators

People with tetraplegia have increased sensitivity of their airways, resulting in more frequent narrowing. To treat this, a family of drugs called *bronchodilators* can be used to enlarge the airways for air to pass through with more ease. The use of bronchodilators is supported by multiple (weak evidence) studies, which have found that bronchodilators can help improve expiration among individuals with tetraplegia. There is also one strong evidence study that indicates that the bronchodilator *salmeterol* can improve both respiratory functioning and the strength of breathing muscles. While bronchodilators can help positively influence respiratory functioning, their use carries a potential negative side effect of thickening mucus.

How can mechanical ventilation be used to help breathing?

Mechanical ventilation, or machine assisted breathing, is becoming more common as there has been an increase in the number of people who survive cervical level injuries over the past 40 years. Mechanical ventilation is used by people who are unable to breathe independently, often right after injury. The machine works by pushing air into the lungs until a pre-set volume or pressure is reached. Once the pre-set value has been met, the machine stops pushing air in and the air is exhaled by the person.

In general, there are two forms of mechanical ventilation: a non-invasive approach where a mask is placed over the mouth and nose (known as a Bilevel Positive Airway Pressure (BiPAP) or Continuous Positive Airway Pressure (or CPAP)), or an invasive approach where a tube is inserted into the windpipe via the mouth and throat (*intubation*) or directly into the windpipe through a surgical incision (*tracheostomy*). Intubation or tracheostomy is used in more severe cases to ensure air gets to the lungs and that mucus is filtered out of the lung. Factors that increase the chances of requiring invasive mechanical ventilation include having a complete injury, having a higher level of injury, or having a *compound injury*. Whenever possible, the healthcare team tries to help people breathe on their own and “weans” the person off the ventilator if possible.

Refer to our article on [Sleep Disordered Breathing](#) for more information about BiPAP!



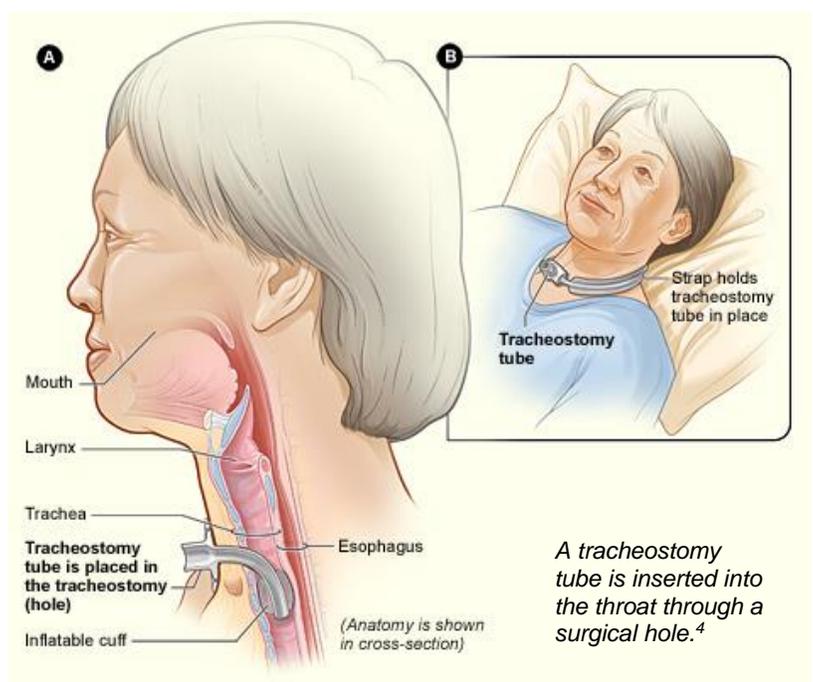
Intubation

The process of *intubation* consists of running a tube into the trachea either through the nose or mouth. This process is completed as soon as someone is in respiratory distress, which is normally at the scene of the accident or upon admission to the hospital. Intubation is often used for a short term (i.e., less than 10 days), as prolonged use can lead to severe weakness of breathing muscles, pneumonia, more difficulty in breathing, mobility limitations, prolonged ventilator weaning, and can make lung and mouth hygiene difficult.

Tracheostomy

A *tracheostomy* is a surgical procedure that involves placing a tube through an opening in the throat and windpipe. This creates a pathway for air delivery from a ventilator and to facilitate secretion removal. However, after the tracheostomy tube is taken out, speaking and eating may be difficult as the throat muscles become weakened and uncoordinated.

A tracheostomy is performed if breathing support is required for a minimum of 3 weeks. Individuals who may require a tracheostomy (weak to moderate



evidence) include: having a complete or higher level of injury, having a complete injury or a lower AIS motor grade, and old age.

Once an individual is able to independently breathe, the tube is removed from the windpipe. Weak evidence suggests that tube removal is more successful in individuals with certain characteristics:

- Those who have lower level spinal cord injuries.
- Those who have not had a tracheostomy but have only been intubated.

Continuous Positive Airway Pressure (CPAP) Ventilation

Continuous Positive Airway Pressure (CPAP) is a form of mechanical ventilation commonly used to address obstructive sleep apnea. Sleep apnea occurs when breathing ceases in short bouts during sleep, and can result in feeling tired during the day. CPAP machines are used to manage this condition by acting as a “pneumatic splint”, keeping airways open during sleep.

What secondary respiratory issues occur with acute SCI?

Loss of independent breathing and cough function can lead to secondary respiratory issues. These issues need to be medically addressed, as they may be life-threatening if left untreated.

Common secondary respiratory issues following SCI

Atelectasis

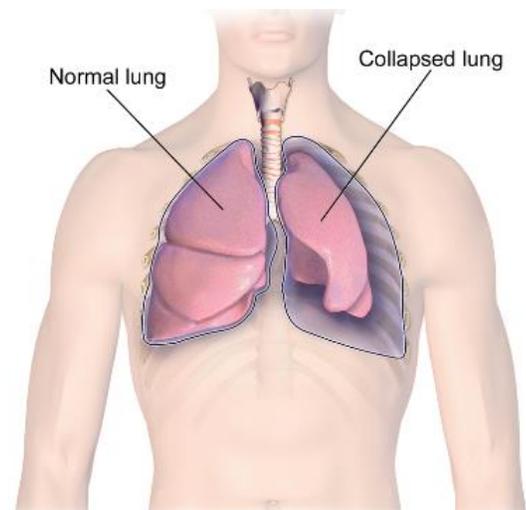
A condition where a part of the lung becomes partially or fully collapsed due to a lack of air. This results in a reduced ability to exchange oxygen and carbon dioxide. When the body does not get enough oxygen, organs will start to shut down. Atelectasis can result from anything that prevents the lungs from fully expanding, including:

- Weak or paralyzed muscles, which can prevent being able to take in a deep full breath. This is the most important cause in SCI.
- A buildup of mucus, which may block an area of the lung from fully expanding.
- Shallow breathing due to surgery or pain, which can result in poor inflation of the lungs.

Pressure from outside the lungs, which can result in the inability to fully inflate. This external pressure may stem from fluid or air, abdominal organs, or external hardware such as a brace.

Pneumonia

Pneumonia is a medical name for a lung infection. After an SCI, several factors make pneumonia very common:



A collapsed lung in comparison to a healthy lung.⁵

- Weak muscles make it hard to get a deep breath in, which means parts of the lung are collapsed and breed bacteria.
- Coughing muscles are not strong enough to get mucus out.
- Poor swallowing (due to throat swelling, uncoordinated swallowing muscles, poor sensation, etc.) which means that food or saliva can go into the lungs instead of into the stomach.
- A weakened immune system.
- Spending more time in hospitals where bacteria is more common.

The risks of getting pneumonia after SCI is a bit higher than when living in the community (i.e., chronic SCI). This is because the airways are more exposed right after injury due to the use of mechanical ventilation, intubation, or requiring surgery to the neck. However, weak evidence has suggested that the chances of getting pneumonia during chronic SCI does not differ from the able-bodied population, although if caught, individuals with SCI may spend a longer duration in the hospital.

Refer to our article on [Infectious Respiratory Conditions](#) for more information!

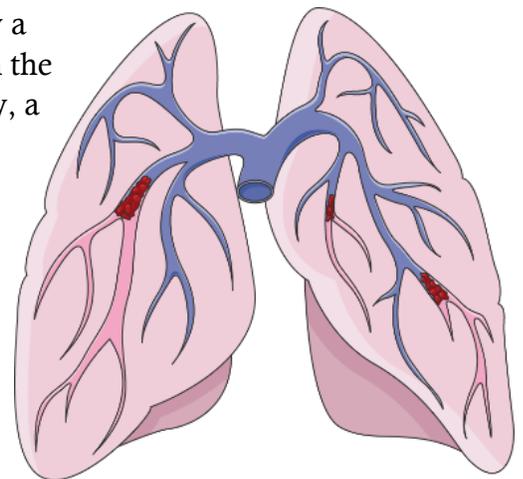


Requiring a ventilator, suctioning (removal of secretions with a special machine), or a tracheostomy may often be necessary, but tends to introduce bacteria despite best efforts at hygiene and air filtration. The risk of getting pneumonia increases if someone:

- is unable to cough and clear mucus,
- is reliant on mechanical ventilation to assist with breathing,
- has a severe injury,
- has a traumatic higher-level injury involving fractures, or,
- has had a surgical tracheostomy.

Pulmonary embolism

A *pulmonary embolism* is a blockage of an artery in the lungs by a blood clot that has moved from elsewhere in the body through the bloodstream (embolism). As a result of paralysis or immobility, a blockage may develop in a vein, often in the lower leg. This is called a blood clot, or *deep vein thrombosis*. The clot may travel to the lung and block blood vessels, resulting in sudden shortness of breath. The prevalence of this condition is highest within the first three months of injury. Weak evidence suggests that pulmonary embolisms occur in a range of 1.25% to 4.5% of people with SCI in the first 90 days. However, pulmonary embolisms have been considered to occur rarely after the first three months of SCI, and have decreased significantly due to preventative measures (e.g., blood thinners). That said, weak evidence suggests that pulmonary embolisms may still be an issue in chronic SCI, but may not be severe enough to cause any symptoms.



A pulmonary embolism occurs when a clot (red groups) gets caught in the lungs.⁶

Pulmonary edema

Pulmonary edema is a build-up of fluid in the lung. This often occurs in early stages following injury. It can affect as much as 50% of individuals with acute tetraplegia. There are several causes, with the most common being excess fluids given to people with SCI. After an SCI, blood pressure may drop to very low levels. Depending on the cause and type of injury, this may be due to blood loss from a traumatic injury, or impairment of nerves that keep blood pressure at its normal level with a cervical or high thoracic injury. As a result, a lot of fluids are given to patients to help their blood pressure recover.

Respiratory failure

Respiratory failure occurs when the respiratory system is damaged to the extent where the body does not get enough oxygen and is unable to get rid of carbon dioxide. Oxygen levels in the body may drop to critically low values and carbon dioxide, which is poisonous at very high levels, builds up. The risk of a respiratory failure increases with higher levels of injury, and most commonly occurs in acute SCI. This usually results in the need for mechanical ventilation.

How are respiratory problems managed and prevented long term?

Prevention is important to avoid getting respiratory illnesses when you have an SCI. Some things you can do to stay as healthy as possible include:

- Avoiding smoking any substances and taking in second hand smoke. The lungs of people with SCI are easily irritated, and those who smoke are more susceptible to lung infections.
- Staying hydrated – drink plenty of water. This helps to keep mucus in the lungs from being too thick.
- Ensuring proper nutrition to help maintain a healthy weight and ensure the body has enough vitamins, minerals and protein to heal well when sick.
- Exercising, as it can help by:
 - Helping you maintain a healthy weight, as lung complications become more prevalent in people who are overweight or obese,
 - Strengthening your breathing muscles.
- Getting vaccinated for influenza (the flu) and pneumonia. This can help decrease your odds of getting these illnesses.
- Coughing on a regular basis. Coughing is important for keeping your airways clear of secretions. If you have difficulties coughing by yourself, have someone help you perform manual assist coughs, or use a cough assist machine.
- Maintaining mobility and proper posture. In order to prevent build up in the lungs, try to sit up everyday and turn when laying in bed.

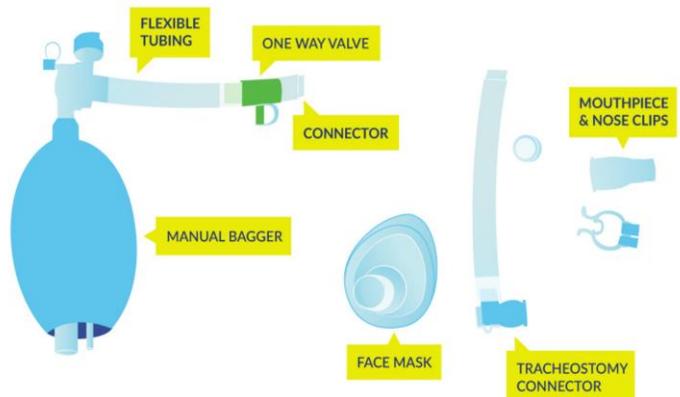


Getting vaccinated is one of the ways to prevent secondary complications such as pneumonia.⁷

Secretion removal techniques

Upon returning to the community, common secretion removal techniques include glossopharyngeal breathing and the use of *lung volume recruitment (LVR) bags* with an assisted cough. *Glossopharyngeal breathing* (or frog breathing) is a technique that is used to get a deeper breath. This is done by rapidly taking “gulps” of breaths one after the other, followed by exhaling. This can help create a cough, or facilitate assisted coughing.

LVR, or “breath stacking” is done with an LVR kit which consists of a resuscitation bag connected with a flexible tube to a mouth piece with a one-way valve. The individual will inhale the most they can, and once this point is reached, a clinician (or second person) will squeeze the bag to “stack” breaths to fully inflate the lungs. This allows the individual to breathe more air than they are able to themselves, and to exhale more air more quickly to produce an improved cough. This also can help with maintaining chest mobility and flexibility.



Equipment used for lung volume recruitment.⁸

Exercise Training

Exercise training involving arm and leg movements can improve muscle strength and cardiovascular endurance. Breathing muscles are also challenged with exercise and may become stronger with exercise. This increase in strength can help decrease the effort of breathing at rest and with functional activity, like transfers. An example of a method of exercise training for individuals with higher levels of injuries include the use of a Functional Electrical Stimulation (FES) bike. Other exercises like arm cycling or strengthening exercises are commonly prescribed by a physiotherapist or health care professional. While exercise can help strengthen respiratory muscles, low-moderate evidence studies debate whether lung volumes are impacted. This is to say, exercising may help make breathing feel easier, but it is unknown whether the amount of air you can take into your lungs is affected. High intensity exercise three times per week for six weeks has shown to significantly improve respiratory function. However, standard guidelines for high intensity exercise have not yet been established.

Refer to our article on [Functional Electrical Stimulation](#) for more information!



An abdominal binder wrapped around the abdomen to correct the positioning of the diaphragm.¹⁰

Girdle/Abdominal Binder

Refer to our article on [Abdominal binders](#) for more information!



Girdles or abdominal binders are garments that apply pressure around the abdominal area to help keep the diaphragm in an optimal position. Abdominal binders are also used for managing orthostatic hypotension and blood pooling. Although there may be short-term improvements when using a girdle or binder, more research is needed in determining their long-term utility.

What is the emerging research on processes to help with breathing?

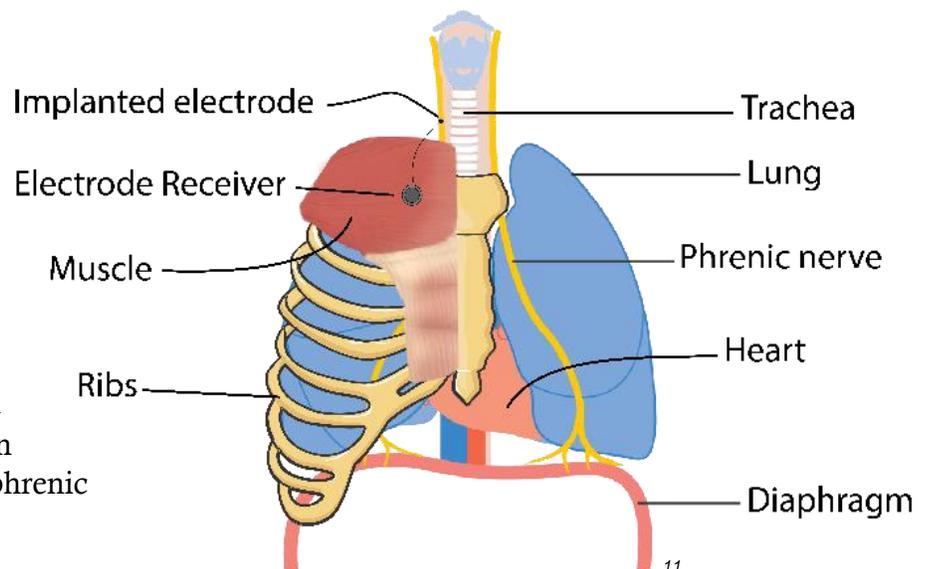
Electrical Stimulation

For people who are ventilator dependent, various electrical stimulation techniques are available to assist with breathing. This includes phrenic nerve stimulation/diaphragm pacing, abdominal electrical stimulation, and epidural stimulation.

Phrenic nerve stimulation/Diaphragm pacing

The diaphragm is the main muscle responsible for breathing and is activated by the *phrenic nerve* to contract. After SCI, the connection between the brain and the phrenic nerve is disrupted, which contributes to impaired breathing. Researchers have been looking at ways we can stimulate this nerve to reactivate the diaphragm through a process called *phrenic nerve stimulation*. This process involves surgically implanting *electrodes* and a receiver close to the phrenic nerve, either in the chest or the neck, and a receiver in the chest wall. This device is controlled with an external remote and antenna (which is used to connect to the electrode receiver).

For phrenic nerve stimulation to work, the diaphragm must have normal function, and the phrenic nerve needs to be intact (i.e., sends a signal when stimulated). As a result, individuals who have a C3, C4, or C5 level injury may not be eligible as they often have impaired phrenic nerve function. It is important to note that this procedure can only facilitate inspiratory functions, but not expiratory. As a result, an individual who receives phrenic nerve stimulation may not require mechanical ventilation, but will still require assistance with coughing and clearing secretions. Tracheostomies and mechanical ventilation are often still used in combination with phrenic nerve stimulation as a back-up.



Some weak evidence supports the use of phrenic nerve stimulation. One study found that diaphragm pacemakers have better results with long term implantation (i.e., 6.3 years in the study). Another study showed that diaphragmatic paces can improve survival rates, decrease the cost of care, improve the quality of speech, increase rates of social participation, and improve management of using a powered wheelchair. Many complications have been reported in the research in regards to using a phrenic nerve stimulator. These complications include wires breaking or getting displaced, device failure, inhaling food when eating, shoulder or abdominal pain, and infections.

Abdominal electrical stimulation

As diaphragm pacing only helps with inhalation, limited research suggests that electrically stimulating the abdominal muscles helps with expiration and coughing. Ideally, the abdominal muscles would be used to support voluntary efforts to cough. There have been mixed findings on the effectiveness of stimulating the abdominal muscles to enhance cough. While some weak studies have found abdominal stimulation to improve cough, other weak evidence studies have found no noticeable changes. More research is required to determine the efficacy of stimulating the abdominal muscles to enhance cough in SCI.

Epidural Stimulation

Epidural stimulation is conducted through surgically implanting an electrode over the spinal cord. Once done, the electrode, which is controlled with a remote outside of the body, stimulates various parts of the spinal cord. Emerging research on epidural stimulation suggests that it may benefit respiratory function after SCI. By directly stimulating nerve cells in the spinal cord, weak evidence suggests that breathing muscles can be activated. The muscles are activated in a pattern that resembles normal breathing, while reducing fatigue. Additionally, weak evidence suggests that epidural stimulation can improve other respiratory functions including coughing and speaking.

Refer to our article on [Epidural Stimulation](#) for more information.



The bottom line

Respiratory problems are common after SCI. The extent and type of these problems depend on the level of injury and completeness of injury. Both conservative and invasive options for managing respiratory health following an SCI are available. Due to impaired respiratory function, a variety of secondary complications to the lungs frequently occur after SCI. While prevention using proper respiratory hygiene is best, should you experience a secondary respiratory complication, a variety of management techniques can be applied. Some techniques are more common in the acute stages of SCI, while others are more suited to chronic SCI. It is best to discuss all treatment options with your health providers to find out which treatments are suitable for you.

For a list of included studies, please see the [Reference List](#). For a review of how we assess evidence at SCIRE Community and advice on making decisions, please see [SCIRE Community Evidence](#).

Related pages

- SCIRE Community. "Inspiratory Muscle Training": community.scireproject.com/topic/inspiratory-muscle-training/
- SCIRE Community. "Sleep Disordered Breathing": community.scireproject.com/topic/sleep-disordered-breathing/
- SCIRE Community. "Infectious Respiratory Conditions": community.scireproject.com/topic/infectious-respiratory-conditions/
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- SCIRE Community. "Abdominal Binders": community.scireproject.com/topic/abdominal-binders/
- SCIRE Community. "Epidural Stimulation": community.scireproject.com/topic/epidural-stimulation/

Reference list

Parts of this page have been adapted from the SCIRE Professional "Respiratory Management during the Acute Phase of Spinal Cord Injury" Module:

Mullen E, Mirkowski M, Vu V, McIntyre A, Teasell RW. (2015). Respiratory Management during the Acute Phase of Spinal Cord Injury. In Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Hsieh JTC, Connolly SJ, Noonan VK, Loh E, McIntyre A, editors. Spinal Cord Injury Research Evidence. Version 5.0: p 1-50.
Available from: scireproject.com/evidence/respiratory-management-acute-phase/

Full reference list available from: community.scireproject.com/topic/respiratory-changes/#reference-list
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