Spinal Cord Injury

Hope Through Research

National Institute of Neurological Disorders and Stroke
National Institutes of Health

Table of Contents

What is a spinal cord injury?

A spinal cord injury (SCI) is damage to the tight bundle of cells and nerves that sends and receives signals from the brain to and from the rest of the body. The spinal cord extends from the lower part of the brain down through the lower back.

SCI can be caused by direct injury to the spinal cord itself or from damage to the tissue and bones (vertebrae) that surround the spinal cord. This damage can result in temporary or permanent changes in sensation, movement, strength, and body functions below the site of injury.

Injury and severity

The extent of disability depends on where along the spinal cord the injury occurs and the severity of the injury.

Loss of nerve function occurs below the level of injury. An injury higher on the spinal cord can cause paralysis in most of the body and affect all limbs (called *tetraplegia* or *quadriplegia*). A lower injury to the spinal cord may cause paralysis affecting the legs and lower body (called *paraplegia*).

The spinal cord extends from the lower part of the brain down through the lower back.

A spinal cord injury can damage a few, many, or almost all of the nerve fibers that cross the site of injury. A variety of cells located in and around the injury site may also die. Some injuries having little or no nerve cell death may allow an almost complete recovery.

Type of injury

A spinal cord injury can be classified as *complete* or *incomplete*.

- An **incomplete injury** means the spinal cord is still able to transmit some messages to or from the brain. People with incomplete injuries retain some sensory function and may have some control of muscle activity below the injury site.
- A **complete injury** means there is no nerve communications and sensory and motor function below the injury site are lost.

Primary damage is immediate and is caused directly by the injury. **Secondary damage** results from inflammation and swelling that can press on the spinal cord and vertebrae, as well as from changes in the activity of cells and cell death.

Common causes

Motor vehicle accidents and catastrophic falls are the most common causes of SCI in the United States. The rest are due to acts of violence (primarily gunshot wounds and assaults), sports injuries, medical or surgical injury, industrial accidents, diseases and conditions that can damage the spinal cord, and other less common causes.

For information on what makes up the spinal cord and spinal column, see the **Appendix** at the end of this document.

What are some signs and symptoms of spinal cord injury?

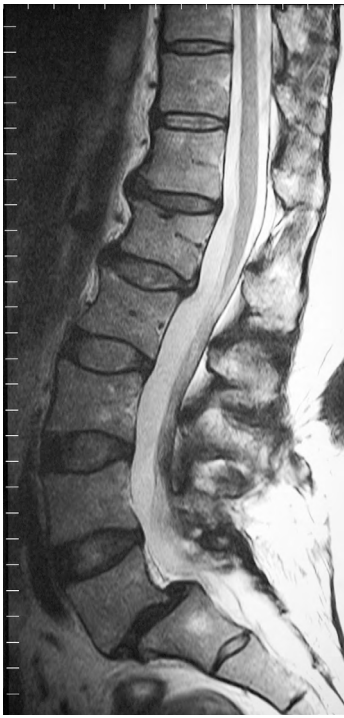
A spinal cord injury can cause one or more symptoms including:

- Numbness, tingling, or a loss of or changes in sensation in the hands and feet.
- Paralysis that may happen immediately or develop over time as swelling and bleeding affects the spinal cord.
- Pain or pressure in head, neck, or back.
- Loss of movement.
- Weakness or inability to move any part of the body.
- Unnatural positions of the spine or head.
- Loss of bladder and bowel control.
- Problems walking.
- Difficulty breathing.
- Changes in sexual function.

How are spinal cord injuries diagnosed?

The emergency room physician will check for movement or sensation at or below the level of injury, as well as proper breathing, responsiveness, and weakness. Emergency medical tests for a spinal cord injury include:

- **Magnetic resonance imaging** (MRI) produces detailed three-dimensional images of body structures, including tissues, organs, bones, and nerves. It can show brain and spinal trauma from injury, herniated discs (cartilage located between the vertebrae), vascular (blood vessel) irregularities, bleeding, inflammation that might compress the spine and spinal cord, and injury to the ligaments that support the cervical spine.
- **Computerized tomography** (CT) provides rapid, clear two-dimensional images of organs, bones, and tissues. CT can detect bone fractures, bleeding, and spinal stenosis (narrowing of the spinal canal).
- **X-rays** show two-dimensional images of most parts of the body, such as a joint or major organ system. Misalignment of or fracture to vertebrae can be seen within minutes.



MRI is one of several emergency medical tests used by physicians to diagnose spinal cord injury. The above image is an MRI of the lumbar region of the spine.

How is SCI treated?

Immediate (acute) treatment

At the accident scene, emergency personnel will put a rigid collar around the neck and carefully place the person on a rigid backboard to prevent further damage to the spinal cord. Sometimes the person may be sedated to relax and prevent movement. A breathing tube may be inserted if the person has problems breathing and the body isn't receiving enough oxygen from the lungs.

Immediate treatment at the trauma center may include:

- Realigning the spine using a rigid brace or mechanical force, which is usually done as soon as possible to stabilize the spine and prevent additional damage.
- Surgery to remove any fractured vertebrae, bone fragments, herniated discs, or other objects that are pressing on the spinal column. Spinal decompression surgery to relieve pressure within the spinal column also may be necessary in the days after injury. Results of a neurosurgical study show that, in some cases, earlier surgery is associated with better functional recovery.

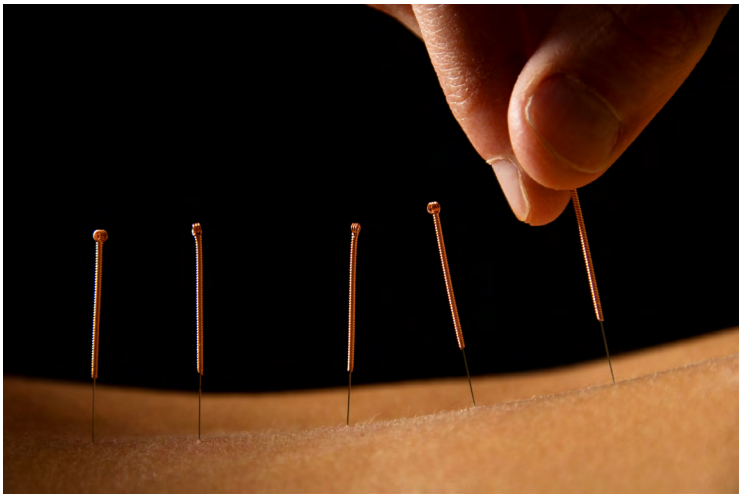
Possible Complications of SCI and treatment

- **Breathing.** About one-third of those with a neck injury will need temporary or permanent help with breathing and may require an inserted artificial breathing tube. Any injury to the spinal cord between the C1-C4 segments (see **Appendix**) can stop breathing, as the nerves in this region cause the diaphragm

to move and the lungs to expand Special training regarding breathing and swallowing may be needed.

- **Pneumonia.** Respiratory complications are the leading cause of death in people with SCI, commonly as a result of pneumonia. People who have an inserted breathing tube and are placed on a ventilator to assist with breathing (called intubation) are at increased risk of developing pneumonia. They must be carefully monitored and treated with antibiotics if symptoms of pneumonia appear. Clearing secretions from the throat and preventing food and liquids from being sucked into the lungs (called aspiration) can prevent pneumonia.
- **Circulatory problems.** Changes in circulation, including blood pressure instability, abnormal heart rhythms (arrhythmias), and blood clots may appear days after the injury. Blood pressure needs to be closely monitored to keep blood and oxygen flowing through the spinal cord tissue. Because the brain's control of the cardiac nerves can be cut off, the heart can beat at a dangerously slow pace, or it can pound rapidly and irregularly. Changes in the control of blood vessels can cause them to widen and allow blood to pool in the small arteries far away from the heart. People with spinal cord injuries are at increased risk for blood clots due to stagnation of blood flow in the large veins in the legs. Treatment includes anticoagulant drugs and compression stockings to increase blood flow in the lower legs and feet.

- **Spasticity and muscle tone.** Reflexes may become exaggerated over time, causing muscle spasticity that may require special treatment. Muscles may waste away due to underuse.
- **Autonomic dysreflexia.** Autonomic dysreflexia is a life-threatening reflex action that primarily affects those with injuries to the neck or upper back. Symptoms may include flushing or sweating, a pounding headache, anxiety, sudden increase in blood pressure, vision changes, or goose bumps on the arms and legs. If possible, the person should be kept in a sitting position, rather than lying flat, to keep blood flowing to the legs and feet and help reduce blood pressure.
- **Pressure sores (or pressure ulcers).** Pressure sores are areas of skin that have broken down because of continuous pressure on the skin and reduced blood flow to the area. People with paraplegia and tetraplegia are susceptible to pressure sores because they may lose all or part of skin sensations and cannot shift their weight. As a result, individuals must be shifted periodically by a caregiver if they cannot shift positions themselves. Special motorized rotating beds may be used to prevent and treat sores.
- **Pain.** Some people who have spinal cord nerve damage develop neurogenic pain—pain or an intense burning or stinging sensation that may be constant due to extreme physical sensitivity (called hypersensitivity) in some parts of the body. It can either be spontaneous or triggered by a variety of factors and can occur even in parts of the body that have lost normal sensation. Treatments for



In addition to medications, treatment for chronic pain may include acupuncture, spinal or brain electrical stimulation, and surgery. Acupuncture involves the application of needles to precise points on the body.

chronic pain include medications, acupuncture, spinal or brain electrical stimulation, and surgery. However, none of these treatments are completely effective at relieving neurogenic pain.

- **Bladder and bowel problems.** Some people may need to use a catheter to empty their bladder or learn ways to empty their bowels. A change in diet may be needed to help with control.
- **Sexual function.** Depending on the level of injury and recovery from the trauma, sexual function and fertility may be affected. A urologist and other specialists can suggest different options for sexual functioning and health.
- **Depression.** Many people living with a spinal cord injury may develop depression due to lifestyle changes. Therapy and medicine may help treat depression.

Once someone has survived the injury and begins to cope psychologically and emotionally, the next concern is how to live with disabilities. Doctors are now able to predict with reasonable accuracy the likely long-term outcome of spinal cord injuries. This helps people experiencing SCI set achievable goals for themselves and gives families and loved ones a realistic set of expectations for the future.

Rehabilitation

Rehabilitation programs combine physical therapies with skill-building activities and counseling to provide social and emotional support, as well as to increase independence and quality of life.

A rehabilitation team is usually led by a doctor specializing in physical medicine and rehabilitation (called a physiatrist) and often includes social workers, physical and occupational therapists, recreational therapists, rehabilitation nurses, rehabilitation psychologists, vocational counselors, nutritionists, a case worker, and other specialists.

In the initial phase of rehabilitation, therapists emphasize regaining communication skills and leg and arm strength. For some individuals, mobility will only be possible with assistive devices such as a walker, leg braces, or a wheelchair. Communication skills such as writing, typing, and using the telephone may also require adaptive devices for some people with tetraplegia.

Rehabilitation combines physical therapy with skill-building activities as well as counseling. A physical therapy program generally includes exercises to improve muscle strength.

- **Physical therapy** includes exercise programs geared toward strengthening muscles.
- **Occupational therapy** helps redevelop fine motor skills, particularly those needed to perform activities of daily living such as getting in and out of a bed, self-grooming, eating, and using a toilet. People may learn how to cope with spasticity, autonomic dysreflexia, and neurogenic pain.
- **Vocational rehabilitation** includes identifying basic work skills and physical and cognitive capabilities to determine the likelihood for employment; identifying potential workplaces and any assistive equipment that will be needed; and arranging for a user-friendly workplace.
- **Educational training** can help people develop skills for a new line of work that may be less dependent upon physical abilities and more dependent upon computer or communication skills. People with SCI or other disabilities are

encouraged to participate in activities that provide a sense of satisfaction and self-esteem, such as educational classes, hobbies, joining special interest groups, and participating in family and community events.

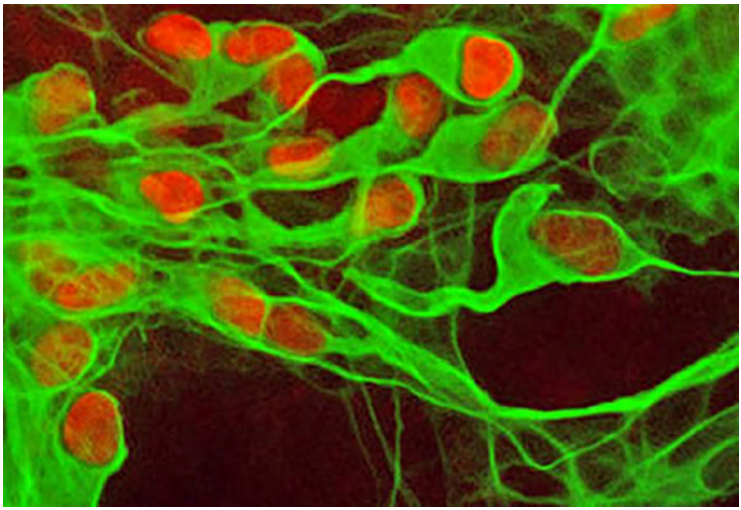
- **Recreation therapy** encourages people with SCI to participate in sports or activities at their level of mobility, as well as achieve a more balanced and normal lifestyle that provides opportunities for socialization and self-expression.

Adaptive devices also may help people with spinal cord injury to regain independence and improve mobility and quality of life. Such devices may include a wheelchair, electronic stimulators, assisted training with walking, neural prostheses (assistive devices that may stimulate the nerves to restore lost functions), computer adaptations, and other computer-assisted technology.

What research is being done?

Scientists continue to investigate new ways to better understand and treat spinal cord injuries.

Much of this research is conducted or funded by the National Institute of Neurological Disorders and Stroke (NINDS). NINDS is a component of the National Institutes of Health (NIH), the leading supporter of biomedical research in the world. Other NIH components, as well as the Department of Veterans Affairs, other Federal agencies, research institutions, and voluntary health organizations, also fund and conduct basic to clinical research related to improvement of function in paralyzed individuals.



Credit: Kit Rodolfa, Harvard University

Researchers are experimenting with a variety of cell-based therapies including stem cell therapy which may eventually allow scientists to add new motor neurons (shown above) in the spinal cord and restore function to persons with spinal cord injury.

The Brain Research through Advancing Innovative Technologies® (BRAIN) Initiative brings together multiple federal agencies and private organizations to develop and apply new technologies to understand how complex circuits of nerve cells enable thinking, movement control, and perception. Research funded as part of the BRAIN Initiative that has the potential to improve the outlook for SCI includes:

- Looking at brain circuits to better understand the sensory and motor basis of behavior.
- Next-generation neural prostheses (devices that connect to the nervous system and restore functions lost due to disease or injury).
- Improved brain and spinal cord imaging.
- New brain-computer interface devices.

Basic spinal cord function research studies how the normal spinal cord develops, processes sensory information, controls movement, and generates

rhythmic patterns (like walking and breathing). Basic studies using cells and animal models provide an essential foundation for developing interventions for spinal cord injury.

Research on injury mechanisms focuses on what causes immediate harm and on the cascade of helpful and harmful bodily reactions that protect from or contribute to damage in the hours and days following a spinal cord injury. This includes testing of neuroprotective interventions in laboratory animals.

Current research on SCI is focused on advancing our understanding of four key principles of spinal cord repair:

- **Neuroprotection**—preventing cell death and protecting surviving nerve cells from further damage, such as drugs to reduce nerve cell death and controlled lowering of the body's core temperature to reduce cell and blood vessel damage and improve functional outcome.
- **Repair and regeneration**—encouraging the spinal cord's intrinsic ability to self-repair and stimulating the regrowth of nerve cell projections (axons) and targeting their connections appropriately, including cell transplants, natural growth-promoting substances, and bioengineered growth scaffolds that allow axons to bridge across the injury site and rebuild neural circuits.
- **Cell-based therapies**—replacing damaged nerve or support cells with other cell types, including stem cells, to regenerate neuronal growth and create new cell connections.

- **Retraining central nervous system circuits** to restore body functions and form new nerve connections and pathways following injury or cell death (called neuroplasticity) through techniques including rehabilitation, electrical stimulation, robot-assisted training, and brain-computer interface technology that may help with voluntary muscle movement and coordination.

Neural engineering strategies build on decades of pioneering NINDS investment that established the field of neural prostheses. For example, researchers are developing a networked functional electrical stimulation system to restore independence through combined implants for hand function, postural control, and bowel and bladder control. NINDS has also led development of experimental brain computer interfaces that enable people to control a computer cursor or robotic arm directly from their brains.

How can I help with research?

Clinical research uses human volunteers—both those who are healthy or may have an illness or disease—to help researchers learn more about a disorder and perhaps find better ways to safely detect, treat, or prevent disease. For information about finding and participating in clinical research visit NIH Clinical Research Trials and You at http://www.nih.gov/health/clinicaltrials. Use search terms such as “spinal cord injury” and “tetraplegia” to access current and completed trials involving spinal injury.

Other centers maintain registries of people interested in participating in ongoing or future clinical research studies. A multi-site network supported by the Christopher and Dana Reeve Foundation called the NeuroRecovery Network also accepts volunteer research participants. For more information, see http://www.christopherreeve.org/site/c.ddJFKRNoFiG/b.5399929/k.6F37/NeuroRecovery_Network.htm.

Clinical research uses human volunteers to help researchers learn more about a disorder such as spinal cord injury.

Where can I get more information?

For more information on neurological disorders or research programs funded by the National Institute of Neurological Disorders and Stroke, contact the Institute's Brain Resources and Information Network (BRAIN) at:

BRAIN
P.O. Box 5801
Bethesda, MD 20824
800-352-9424

Information on SCI also can be found at:

Christopher and Dana Reeve Foundation
Information@christopherreeve.org
973-379-2690 or 800-225-0292

Miami Project to Cure Paralysis
miamiproject@miami.edu
305-243-6001 or 800-782-6387

National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR)
202-401-4634; 202-245-7316 (TTY)

National Rehabilitation Information Center (NARIC)
naricinfo@heitechservices.com
301-459-5900; 800-346-2742; 301-459-5984 (TTY)

Paralyzed Veterans of America (PVA)
info@pva.orr
800-424-8200

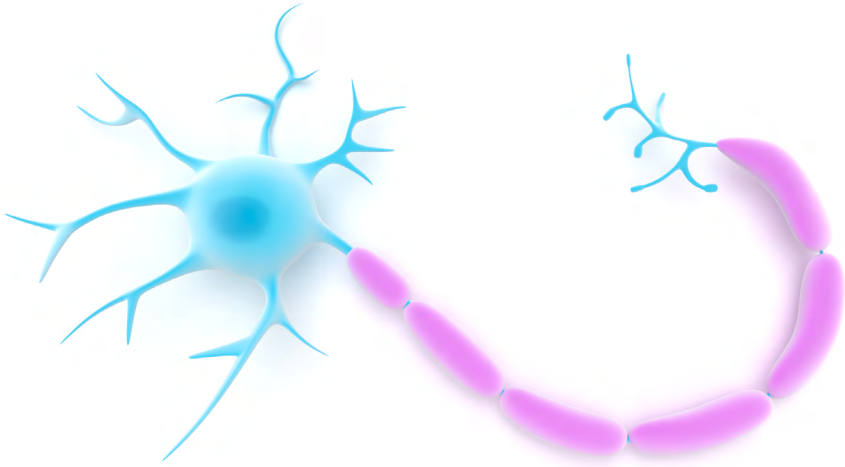
United Spinal Association
askus@unitedspinal.org
718-803-3782 or 800-962-9629

Appendix

Anatomy of the spinal cord

The spinal cord is a soft, cylindrical column of tightly bundled nerve cells (neurons and glia), nerve fibers that transmit nerve signals (called axons), and blood vessels. It sends and receives information between the brain and the rest of the body. Millions of nerve cells situated in the spinal cord itself also coordinate complex patterns of movements such as rhythmic breathing and walking.

The spinal cord extends from the brain to the lower back through a canal in the center of the bones of the spine. Like the brain, the spinal cord is protected by three layers of tissue and is surrounded by the cerebrospinal fluid that acts as a cushion against shock or injury.



The spinal cord consists of nerve cells (like the one shown above), nerve fibers, and blood vessels.

Inside the spinal cord is:

- A collection of neurons and their projections that connect with other nerve cells to transmit and receive information, called gray matter.
- Bundles of axons, some of which are coated with a whitish mixture of proteins and fat-like substances, called white matter.

Other types of nerve cells sit just outside the spinal cord and relay information to the brain.

31 pairs of nerves, each of which contains thousands of axons, are divided into 4 regions having individual segments and link the spinal cord to muscles and other parts of the body:

- *Cervical* spinal nerves (C1 to C8) emerge from the spinal cord in the neck and control signals to the back of the head, the neck and shoulders, the arms and hands, and the diaphragm.
- *Thoracic* spinal nerves (T1 to T12) emerge from the spinal cord in the upper mid-back and control signals to the chest muscles, some muscles of the back, and many organ systems, including parts of the abdomen.
- *Lumbar* spinal nerves (L1 to L5) emerge from the spinal cord in the low back and control signals to the lower parts of the abdomen and the back, the buttocks, some parts of the external genital organs, and parts of the leg.
- *Sacral* spinal nerves (S1 to S5) emerge from the spinal cord in the low back and control signals to the thighs and lower parts of the legs, the feet, most of the external genital organs, and the area around the anus.

- The spinal column, which surrounds and protects the spinal cord, is made up of 33 rings of bone (called vertebrae), pads of semi-rigid cartilage (called discs), and narrow spaces called foramen that act as passages for spinal nerves to travel to and from the rest of the body. These are places where the spinal cord is particularly vulnerable to direct injury.

National Institute of
Neurological Disorders
and Stroke

NIH . . . Turning Discovery Into Health

Prepared by:

Office of Neuroscience Communications and Engagement
National Institute of Neurological Disorders and Stroke
National Institutes of Health
Bethesda, Maryland 20892

Like us on Facebook:
@NINDSBrainForLife
https://www.facebook.com/NINDSBrainForLife

Follow us on Twitter:
@NINDSnews
https://twitter.com/NINDSnews

Publication No. 21-NS-160
June 2021