Care Considerations for Patients With Spinal Cord Injuries

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After completing this article, the reader should be able to:
- Summarize the incidence and prevalence of spinal cord injury in the United States.
- Explain the difference between tetraplegia and paraplegia.
- Explain the categories of complete and incomplete spinal cord injuries.
- Describe the pathophysiology of autonomic dysreflexia.
- Discuss how prompt intervention is vital to avoid a life-threatening situation with autonomic dysreflexia.
- Describe the various stages of pressure ulcers.
- Discuss future treatment options for people who have spinal cord injuries.
- Understand the physical and emotional needs of patients with spinal cord injuries.

A spinal cord injury has a tremendous effect on an individual’s physical and mental health. Besides causing paralysis, spinal cord injuries lead to chronic medical conditions, adjustments in employment or educational goals, changes to personal and sexual relationships, and more. As many as 327,000 people affected by spinal cord injury are living in the United States today, with an average age of injury of approximately 41 years. Costs to treat people with spinal cord injuries the first year after injury can be as high as $1 million, and subsequent care costs range as high as $178,000 per year.

Spinal cord injury patients undergoing medical diagnostic imaging warrant special care and consideration. Therefore, radiologic technologists must obtain a thorough understanding of the medical management of patients with spinal cord injuries so radiologic examinations involving this patient population can proceed safely and produce quality images. The radiologic technologist should demonstrate competence in caring for these patients’ unique needs.

Anatomy of the Spine

The vertebral column, also called the spinal column, is the central support of the body and bony protection for the spinal cord and nerves. The column has 5 regions: cervical, thoracic, lumbar, sacral, and the coccyx. The cervical region consists of 7 vertebrae that allow the head to rotate from a fixed point. The first 2 cervical vertebrae have unique morphology that allows the head to move forward and backward, rotate, tilt, and lift. The first cervical vertebra is the atlas, which articulates with the occipital bone at the base of the skull to make up the condylar joint, which allows backward and forward...

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motion of the head. The inferior surface of the atlas articulates with the second cervical vertebra, the axis.

Twelve thoracic vertebrae descend through the thorax and attach to the rib cage. The lumbar region has 5 large vertebrae that support most of the body’s weight. The sacral region is inferior to the lumbar spine; it is composed of 5 fused vertebrae from which the bones of the pelvis articulate. The coccyx is the smallest and final segment of the bony spinal column, consisting of 4 to 5 extremely small, sealed vertebrae (see Figure 1).

The spinal column has an opening called a central foramen through which the spinal cord passes. The spinal cord is a sophisticated structure of nerves that relay information to and from the brain about sensations, movement, and autonomic functions. The spinal cord begins at the caudal end of the medulla oblongata in the brain at the base of the skull from the foramen magnum. The cord then descends through the cervical, thoracic, and lumbar vertebrae and ends between the L1 and L2 vertebrae. The end of the spinal cord forms a cone-shaped structure composed of a collection of nerves called the conus medullaris. The conus medullaris consists primarily of sacral spinal cord segments and provides critical sensory innervation to what is known as the “saddle area.” This includes motor innervation for the sphincters and parasympathetic innervation for the bladder and rectum. Inferior to the conus medullaris, the individual lumbar and sacral nerves extend beyond the spinal cord. These nerve bundles are called the cauda equina because they resemble a horse’s tail. A single fibrous strand called the filum terminale anchors the spinal cord at the coccyx (see Figure 2).

The spinal cord is made up of gray and white matter. Gray matter extends through the internal spinal cord and is composed of interneurons and motor neurons. Interneurons act as relay switches between the motor neurons. They also are found in between sensory neurons; however, an interneuron would not connect a sensory neuron with a motor neuron. Motor neurons conduct impulses from the central nervous system to the muscles or glands, and sensory neurons carry impulses from receptors in the skin, skeletal muscles, joints, and internal organs to the central nervous system. Motor nerves comprise only motor neurons, and sensory nerves comprise only sensory neurons.

Thirty-one pairs of spinal nerves emerge from the spinal cord. There are 8 cervical nerves, 12 thoracic nerves, 5 lumbar nerves, 5 sacral nerves, and 1 pair of coccygeal nerves. All of these nerves radiate out of the spinal canal through the intervertebral foramina, small openings between spinal vertebrae. For the first 7 cervical vertebrae the spinal nerves pass through the intervertebral foramina above the cervical vertebra that corresponds to that number. For example, the fifth cervical nerve passes through the foramina above the C5 vertebra. Because there are 8 cervical nerves and only 7 cervical vertebrae, the eighth cervical nerve passes above the T1 vertebra. From this point all subsequent spinal nerves running through the thoracic, lumbar, sacral, and coccygeal regions emerge from the intervertebral foramina below the vertebra with that same number (see Figure 3).
Each spinal nerve has a dorsal and ventral root. The dorsal root is made of sensory neurons that carry impulses into the spinal cord. The ventral root is the motor root, made of the axons of motor neurons that carry impulses from the spinal cord to muscles or glands (see Figure 4). Axons transmit electrical stimulation onto dendrites, branching projections that provide a larger surface area to pass a chemical signal to many target cells simultaneously. The white matter of the spinal cord envelops the gray matter and comprises myelin-covered axons and dendrites of interneurons. Myelin is a white fat and protein layer that insulates the axons. These axons and dendrites are grouped into 2 nerve tracts: ascending and descending. Sensations such as touch, pain, heat, cold, and position are transmitted via the ascending tracts. The nerve impulses move up from the body at the point of origin to the brain, where the signal is processed. The descending nerve tracts carry information from the brain to the rest of the body to create movement and control certain organ functions. Sensory innervation to the saddle area controls the sphincters and the parasympathetic impulses to control the bladder and the lower bowel.

Other specialized nerve cells called sensory ganglia are found in dense clumps just outside of the spinal cord. Their function is to relay information regarding pain, touch, temperature, vibration, pressure, and joint position back to centers in the brain.

The spinal cord is similar to the brain in that it is enclosed by 3 distinct membranes called meninges. The tough outer layer is the dura mater, the middle layer is the arachnoid mater, and the delicate inner layer is referred to as the pia mater.
Epidemiology of Spinal Cord Injuries

Estimates of the incidence and prevalence of spinal cord injury in the United States vary depending on the source. However, there are approximately 12,000 new cases of spinal cord injury in the United States every year, which is an incidence rate of 40 cases per 1 million people. The prevalence of spinal cord injury in the United States ranges from 238,000 to 332,000 people. Advances in acute medical care have made it possible for more than 65% of individuals who receive these injuries to survive their initial injury. Data about these spinal cord injuries as well as treatment outcomes after the injury are collected by the National Spinal Cord Injury Statistical Center. The most common causes of spinal cord injury in the United States are motor vehicle accidents, violence, sports injuries, and falls. The elderly population, those aged older than 65, are most likely to sustain a spinal cord injury from a fall. In the 1990s spinal cord injury due to violence peaked but has steadily declined since then. Sports-related injuries related to trampoline accidents, football, and diving also have declined because of increased training and proper safety equipment.

Pediatric populations have the lowest incidence rates for spinal cord injury. The highest rates of spinal cord injury are attributed to people in their late teens to early 20s. However, some studies suggest that as the percentage of elderly persons older than 65 years of age increases in the United States, there is a slight increase in incidence of spinal cord injury among this population. Gender is a significant risk factor, with 71% of all reported spinal cord injuries occurring in men. Data collected in the United States suggests that only 29% of spinal cord injury patients are women. According to data from the International Spinal Cord Society, the incidence and prevalence of trauma resulting in spinal cord injury is higher in the United States than in the rest of the world. Evidence also shows that the relative proportion of higher injury sites (i.e., at the cervical spine) is increasing, along with injuries caused by falls.

Traumatic Spinal Cord Injury

Traumatic spinal cord injury is a serious and life-altering event. Most blunt trauma from falls, automobile accidents, and injuries from gunshot wounds, knives, and other penetrating trauma usually do not completely sever the
spinal cord. If the vertebrae are broken or dislocated, they can put harmful pressure on the spinal cord. Pressure from the vertebrae crushes and destroys the sensitive axons that carry signals. Minor injuries to the spinal cord seldom cause nerve cell death, but patients might experience pressure-induced blockage of nerve signals or demyelination without axonal damage. Patients who have minor injuries usually recover.

When a severe injury occurs to the vertebrae, however, the pressure from the injury can cause complete cell death across a horizontal level of the spinal cord, which can result in complete paralysis. Severe injuries usually occur from a sudden and powerful mechanical blow to the spine, and damage to the nerve cells commences at the moment of primary injury. Bleeding into or just outside of the spinal cord also can cause pressure-induced damage.

Spinal shock is a serious condition and is the loss of all neurological activity below the level of injury. During an episode of spinal shock, the spinal cord below the level of injury is rendered completely paralyzed and is temporarily disabled, resulting in complete paralysis and loss of all reflexes and sensation. Spinal shock can begin 30 to 60 minutes following a traumatic spinal injury and last up to 6 weeks. Secondary injury follows, resulting in additional damage from changes in blood flow, excessive release of neurotransmitters, invasion of immune system cells that cause inflammation through the breached blood-brain barrier, free radical attack on the nerve cells, self-destruction of nerve cells (apoptosis), and scarring. The scarring results in a physical and chemical barrier that limits or stops conduction of any remaining nerve signals.

**Classification of Spinal Cord Injuries**

The American Spinal Injury Association (ASIA) first published standards to classify spinal cord injury in 1982. The ASIA classifications include neurological level of injury and identification of corresponding muscles and sensation. In 1992, the International Medical Society of Paraplegia refined the ASIA classifications and established international standards. Finally, a standardized ASIA Impairment Scale was developed and instituted to classify spinal cord injury by neurologic level.

The impairment scale classifies a person’s limitation from spinal cord injury in grades of A, B, C, D, and E corresponding to the extent of injury. According to the scale, a complete injury represents the absence of sensory and motor function in the lowest sacral segments. An incomplete injury involves some sensory or motor function below the level of injury, including the sacral segments. The ASIA muscle grading scale ranges from 0 to 5* with 0 indicating total paralysis, and 5* indicating normal muscle exertion. The ASIA impairment scale is summarized in Table 1.

The concept of complete or incomplete injury, frequently referred to as severity of injury, is often not well understood. Complete injury does not refer to a spinal cord that has been completely severed or transected. A complete injury represents a total absence of sensory and motor functions below the site of the injury. An incomplete classification represents preservation of some sensory or motor functions below the level of injury, including the lowest sacral segments.

**Paraplegia** is a term that denotes paralysis of the lower half of the body, usually affecting both legs, and primarily as a result of disease or injury to the spinal cord. The injury usually occurs in the thoracic, lumbar, or sacral segments and may occur in the cauda
equina or the conus medullaris.\textsuperscript{13} \textit{Tetraplegia} (formerly known as \textit{quadriplegia}), is paralysis of the arms, trunk, pelvic organs, and legs below the level of an injury to the spinal cord in the cervical region. Impairment or loss of motor and sensory functions in the cervical spine is usually caused by injury to the cervical vertebrae in the area of C5 through C7 (see Figure 6).\textsuperscript{13}

Injuries that occur above C5 can result in immediate, life-threatening cardiovascular complications as a result of a blocked sympathetic nervous system. Respiratory failure is the major cause of death after such an injury. Low body temperature, impaired peristalsis, bradycardia, and autonomic dysreflexia are other symptoms of these types of spinal cord injuries.\textsuperscript{17} Autonomic dysreflexia is an acute medical emergency resulting in life-threatening hypertension.\textsuperscript{18}

### Autonomic Dysreflexia

Autonomic dysreflexia is a potentially life-threatening medical emergency that affects 50% to 90% of people with spinal cord injuries from T6 and above, and sometimes from T10 and above.\textsuperscript{19-21} Autonomic dysreflexia does not occur in people with healthy spinal cords. The condition seems to be most common in adult patients with new traumatic injuries, with a level of injury at or above T6.\textsuperscript{15} Many of these patients are admitted to an intensive care unit immediately after injury because of their risk for autonomic dysreflexia.

### Table 1

<table>
<thead>
<tr>
<th>Category</th>
<th>Extent of Injury</th>
<th>Function</th>
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<tbody>
<tr>
<td>A</td>
<td>Complete</td>
<td>Complete impairment with no sensory or motor function in sacral segments S4 through S5</td>
</tr>
<tr>
<td>B</td>
<td>Incomplete</td>
<td>Some sensory but no motor functions below the injury site</td>
</tr>
<tr>
<td>C</td>
<td>Incomplete</td>
<td>Motor function preservation below the neurologic injury level; most key muscles below the injury level have a muscle grade (&lt; 3^a)</td>
</tr>
<tr>
<td>D</td>
<td>Incomplete</td>
<td>Motor function preservation below the injury site; key muscle grade of (\leq 3^a)</td>
</tr>
<tr>
<td>E</td>
<td>Normal</td>
<td>Normal sensory and motor functions</td>
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\textsuperscript{a} Muscle grade indicates the severity of muscle weakness.

Figure 6. Spinal cord injury locations resulting in tetraplegia and paraplegia. Used with permission from apparelyzed.com.
The general signs and symptoms of autonomic dysreflexia include a sudden increase in blood pressure, reflex bradycardia, anxiety, blurred vision, headache, sweating, blotching of the skin, flushing above the area of injury, and restlessness. In regard to pediatric patients with spinal cord injuries, a significant gap occurs in the literature relative to understanding the symptoms of autonomic dysreflexia. In contrast to adults with spinal cord injuries, autonomic dysreflexia manifests in children as a result of developmental variations in blood pressure, their ability to communicate, and varying dependencies upon parents or caregivers. Signs and symptoms of the condition in children are facial flushing, headache, sweating, and piloerection. Autonomic dysreflexia has been linked to myocardial ischemia and fatal cerebral hemorrhage.

Sympathetic output from the spinal cord normally is modulated by input from the higher brain centers. After a spinal cord injury, this input is no longer available, so there is no way for the body to return to homeostasis. Autonomic dysreflexia involves the interruption of descending inhibition and the development of an exaggerated hyper-responsiveness of the peripheral receptors. Activation of baroreceptors combined with a vagal-mediated response from an area of the spinal cord above the lesion causes bradycardia from the hypertensive crisis.

There are a number of causes of autonomic dysreflexia and sometimes the condition is asymptomatic. Stimulation of presacral or pelvic nerves could be one of the trigger mechanisms in patients with suprasacral spinal cord injury. Noxious stimuli—unpleasant sensations—travel upward to the spinal cord through the lateral spinal thalamic tracts and the dorsal columns. This impulse sparks a massive uninhibited sympathetic response through the intermediolateral cell column. Under normal conditions (in people with neurologically intact systems), the response is moderated by central inhibition, but for those with spinal cord injuries, the unopposed and pulsing sympathetic response induces severe hypertension.

In a cascading effect, the carotid sinus and aortic body baroreceptors stimulate the vasomotor center in the brain stem, which results in a vagal response precipitating autonomic dysreflexia symptoms. This leads to vasodilation above the spinal cord injury and vasoconstriction below the level of the injury. Patients with spinal cord injuries might have an increased responsiveness to vasopressors which could be due, in part, to increased reactivity of resistance vessels or decreased neuronal reuptake from the synaptic cleft.

The most common cause of autonomic dysreflexia is distension of the bladder, which can be caused by a kink in the urinary catheter, kidney stones, or infection of the urinary tract. Autonomic dysreflexia also can be caused by fecal impaction, pressure sores, fractures, menstruation, hemorrhoids, ingrown toenails, invasive testing, and sexual intercourse. Sometimes even seemingly harmless stimuli such as a crease in the bed sheet, sunburn, or a shoelace tied too tightly may invoke an episode of autonomic dysreflexia in patients with spinal cord injuries. In most cases, the condition will not resolve on its own after the stimulus is removed.

The key to prevention of autonomic dysreflexia in patients with spinal cord injuries is awareness of the triggers. Autonomic dysreflexia always should be anticipated, and caregivers should take appropriate precautions so they can respond immediately. This is particularly important in patients with high-level cord injuries. Radiologic technologists should speak with nurses certified in spinal cord injury care, nurse practitioners, physician assistants, or physician specialists before performing diagnostic examinations or interventional procedures to take steps to prevent iatrogenically (inadvertently) induced autonomic dysreflexia. Special attention should be placed on Foley/suprapubic catheters when transferring patients to and from examination tables so the tubing doesn’t become kinked or twisted. Catheter disruptions can lead to urinary retention, impaired outflow, and possible autonomic dysreflexia, according to Juan Asanza, MD (written communication, October 2013). Seventy-five percent of autonomic dysreflexia cases in pediatric patients are caused by urological issues (bladder distension being the most common trigger). Bowel impaction is another common cause.

A lack of awareness about the symptoms of autonomic dysreflexia could lead to fatal complications in patients. Table 2 shows guidelines for identification and treatment of symptoms. Prompt identification
of this condition and rapid intervention are critically important to avoid death from autonomic dysreflexia in patients with spinal cord injury. If a radiologic technologist or radiologist suspects a patient is showing signs of autonomic dysreflexia, he or she should monitor vital signs, with a focus on blood pressure. The spinal cord injury unit, nurse, or provider should be contacted immediately for assistance.

Considerations for Continuing Care Bladder

Patients with spinal cord injuries should be monitored continuously for proper bladder management. Many of these patients do not have control over bladder functions because muscles in the lower urinary tract are often affected by spinal cord injury. These muscles include the detrusor muscle of the bladder and the valve muscles that open and close the sphincters in the bladder. The physiology of normal bladder function involves the brain stem and the spinal cord working in concert to keep the bladder relaxed and the sphincter muscles contracted so urine can fill the urinary bladder and not enter the urethra. During normal urination, the bladder contracts and the sphincter opens to allow urine to exit the bladder and enter the urethra. After a spinal cord injury a number of problems can occur in this normal bladder function, depending on the severity and level of the injury. Nerve-related lack of bladder control is known as neurogenic bladder. Each individual might prefer a different method of bladder management because of convenience, safety, and risk factors. The goal is to select the management system with the least morbidity and the highest ease of use for each particular patient.

Suprapubic catheterization involves placing a catheter through the skin, subcutaneous tissue, and the rectal sheath into the retropubic space until it enters the bladder. To avoid complications during the procedure, ultrasonography

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**Table 2**

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<thead>
<tr>
<th>Guidelines for Treating Autonomic Dysreflexia</th>
<th>Rationale</th>
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<tbody>
<tr>
<td>Procedure</td>
<td>Rationale</td>
</tr>
<tr>
<td>Sit the patient upright.</td>
<td>This induces orthostatic hypotension to counter the hypertension.</td>
</tr>
<tr>
<td>Check in with the patient; ask if he or she suspects a cause of the symptoms.</td>
<td>Patients with spinal cord injuries often recognize the onset of autonomic dysreflexia and usually can assist health professionals. However, this might not be true for patients with a new injury.</td>
</tr>
<tr>
<td>Loosen or remove any restrictive clothing, including shoes.</td>
<td>Removing restrictive items relieves noxious stimuli.</td>
</tr>
<tr>
<td>Perform a survey of other possible causes of autonomic dysreflexia, beginning with bladder distention.</td>
<td>Urinary tract noxious stimuli is the usual cause of most cases of autonomic dysreflexia. Check for a kinked urinary drainage tube and ask the patient when his or her bladder was last emptied.</td>
</tr>
<tr>
<td>Check for fecal impaction.</td>
<td>Noxious stimuli resulting from fecal impaction can trigger autonomic dysreflexia. Ask the patient when bowel care was performed last and whether it was successful.</td>
</tr>
<tr>
<td>Perform a quick survey and assess the patient for bruising or recent injury. Check for fractures and hip dislocation.</td>
<td>Patients with spinal cord injuries might not feel the pain from a new fracture or dislocation and might not be aware it occurred.</td>
</tr>
<tr>
<td>Check for skin problems, pressure ulcers, infections, or burns.</td>
<td>These problems may be related to noxious stimulus below the level of injury.</td>
</tr>
<tr>
<td>If the patient’s systolic blood pressure remains above 150 mm Hg, administer a short- and fast-acting antihypertensive agent such as sublingual nifedipine or an intravenous agent of hydralazine or diazoxide.</td>
<td>Antihypertensive agents will relieve the dangerous blood pressure.</td>
</tr>
</tbody>
</table>
is used to ensure proper location and placement of the catheter. Complications of this procedure include bowel perforation and intra-abdominal visceral injuries. Other complications from suprapubic catheterization include leakage from the site or urethra, revision of the tube, and general surgical complications. A 2010 study by Katsumi et al suggested that morbidity from suprapubic catheter placement procedures might outweigh the benefits.

An alternative to the suprapubic catheter is a procedure known as clean intermittent catheterization. Clean intermittent catheterization alone or in combination with other methods of emptying the bladder is the most common method of bladder management among people with spinal cord injuries. The introduction of clean intermittent catheterization has led to remarkable improvements in problems associated with bladder incontinence. Clean intermittent catheterization involves inserting a urinary catheter, using sterile technique, via the urethra and into the bladder. A Swedish study found that patients using hydrophilic, low-friction techniques and catheters do as well as or better than patients with conventional catheters, and the authors demonstrated that use of the low-friction catheter seems to prevent urethral trauma and strictures.

Another option for bladder management is using conventional indwelling urethral catheters. Urologists avoid use of indwelling urinary catheters because of high infection and morbidity rates. Complications of the indwelling urinary catheter include urinary tract infection, ventral urethral erosion, and urethral fistula formation. Before 1940, patients with spinal cord injuries often died from complications of urinary tract infections a few months after the injury. After the advent of antibiotics later in that decade, deaths from urinary tract infections were replaced by kidney failure as the leading cause of death in patients with spinal cord injuries. Advances in clinical management and technology have reduced these deaths to 3% of patients with spinal cord injuries.

A study conducted at the Long Beach Veterans Administration Medical Center followed more than 600 men with spinal cord injuries who had sustained injuries between 1945 and 2007. The authors compared complications from indwelling urinary catheters vs indwelling suprapubic catheters. Morbidity associated with suprapubic catheterization offset any benefit from the slightly reduced complication rate related to using an indwelling urinary catheter. In addition, the authors found a similar rate of complications such as urinary tract infection, recurrent bladder and renal calculi, and development of cancer with both types of catheterization. Bladder cancer was listed as one of the most severe complications of the indwelling urinary catheter because of the development of squamous cell carcinoma. In the study, 2% to 10% of the patients developed cancer, and 80% of the participants in the sample had squamous changes in the bladder mucosa. The authors concluded that people with spinal cord injuries requiring chronic indwelling catheters for neurogenic bladders (regardless of type) should collaborate with their physician to select the catheter type based on long-term comfort and flexibility.

To minimize the occurrence of autonomic dysreflexia, radiologic technologists should help maintain proper urinary drainage for patients with spinal cord injuries who are undergoing imaging examinations. A simple assessment of the urinary drainage tubing and device is essential. If a patient has a urinary drainage bag, technologists should ensure that the tubing has not kinked in transport and that urine is flowing with gravity. A bent or occluded drainage tube can cause urine to build up in the bladder, potentially leading to a life-threatening episode of autonomic dysreflexia.

Radiologic technologists also should be aware that from a psychosocial point of view, loss of bladder control might diminish a patient’s subjective well-being. Nevertheless, patients with spinal cord injuries are accustomed to inquiries about bladder and bowel management, so imaging professionals need not feel apprehensive about asking these patients questions regarding bladder management. Because bladder and bowel issues are the 2 most common causes of autonomic dysreflexia in patients with spinal cord injuries, technologists must remain vigilant when these patients are in their care.

Bowel Considerations
Dysfunction of the bowel (eg, fecal incontinence, severe constipation, flatulence, and hemorrhoids)
in patients with spinal cord injuries is an important concern because of its role in quality-of-life issues and reintegration into the community. In a study of patients with spinal cord injuries published by Coggrave et al in 2009, respondents in the United Kingdom listed bowel dysfunction as the number one contributor to injury-related impairments. One of the first items that new patients face during rehabilitation is how to manage their bowel program. A patient-centered approach must be used to create a unique program that works for these individuals and their caregivers. The interdisciplinary team must educate patients regarding their altered physiology after a spinal cord injury to implement an effective bowel care program.

Compilation of a baseline medical history for neurogenic bowel should be completed before implementing a bowel care program. This baseline assessment should include a premorbid history for daily fluid intake, diet (to include how much fiber the patient consumes, frequency of meals, and timing of meals), bowel movement frequency, the duration of the bowel movement, and a survey of the stool consistency (to include color, mucus, blood, and form). The baseline medical history for neurogenic bowel should include lifestyle goals, such as returning to the community, work and school schedules, and the amount of time needed to complete the bowel care regime. Once an effective bowel care program is established, the patient should strictly adhere to the program.

The time of day and frequency of bowel care can be adjusted to coincide with convenience for the patient and caregiver. Clinical guidelines for spinal cord injury medicine recommend that bowel care be completed no less than 3 times a week. Patients who neglect bowel care risk excessive buildup of stool in the bowel, which can become dry, less plastic, and difficult to eliminate. This accumulation of fecal matter stretches the colon, which adversely affects peristalsis, and renders the normal bowel care program ineffective. Bowel movements significantly affect health, well-being, self-esteem, modesty, and integration into the community. Because individuals with spinal cord injuries are unable to detect the sensation to defecate, control the anal sphincter, or sometimes position themselves for defecation, clean-up, and odor control, it is imperative that a preemptive strategy for regular and effective bowel management be fully implemented.

A correlation might exist between advancing age, length of time since injury, and changes in bowel function as a result of greater laxative use, use of strong rectal stimulants over time, and increased use of digital stimulation. Therefore, bowel function most likely deteriorates with time in people with spinal cord injuries. A recent study conducted in Korea by Kim et al reiterated that factors related to bowel care such as fecal incontinence, time in one defecation greater than 60 minutes, perianal skin irritations, and hemorrhoids are the factors that most greatly diminish the self-reported quality-of-life score.

Management of a neurogenic bowel includes stimulating the patient by chemical or physical methods. The patient also must be placed into a suitable position for defecation (usually a lateral recumbent position) and must be prepared to defecate. Some of the stimulation methods include digital rectal stimulation, manual evacuation, use of suppositories, and enemas. The most common form of defecation stimulation used in early rehabilitation is digital rectal stimulation, a procedure in which a gloved and lubricated finger is inserted into the rectum of the patient and rotated in a clockwise or counterclockwise motion to dilate and relax the distal rectum and anal canal. The continued rectal mucosal contact provides the stimulation for peristalsis and allows the fecal material, mucus, and gas to descend. Digital rotation continues until the bowel wall relaxes, flatus passes, stool is expelled, or the internal sphincter tightens. Digital rectal stimulation activates the recto-anal inhibitory reflex, which relaxes the internal sphincter, and the rectocolic reflex, which stimulates the pelvic nerve to commence peristalsis. The digital stimulation continues, and as stool descends, it is removed. This continues over a period of time until nothing but mucus is returned. At this point, the bowel care program is complete, and the patient can be cleaned.

In the Korean study, surveys were sent to 370 people with spinal cord injuries with questions regarding defecation stimulation methods. Twenty-four percent of the respondents indicated they could defecate without stimulation, almost 60% responded that they used only one method, and approximately 12% indicated they used 2 or more bowel-care methods.
Patients with spinal cord injuries undergoing radiologic examinations or interventional procedures may or may not have had their scheduled bowel care before arriving in the radiology department. These patients are accustomed to managed bowel care programs, so technologists need not be apprehensive about asking patients if they have had bowel care. In addition, patients who have spinal cord injuries may be unaware that they have had an episode of incontinence or flatus because they might have absent or diminished sensation. Technologists should be prepared for this occurrence and should be ready to assist the patient. If the patient indicates a need for bowel care, radiology personnel should immediately contact the caregiver for assistance.

Pressure Ulcers

Pressure ulcers pose one of the greatest risks to the overall health and well-being of people who have spinal cord injuries, and many questions remain regarding how best to prevent and manage skin breakdown and subsequent pressure ulcer development. A pressure ulcer is localized injury to the skin or underlying tissue, usually over a bony prominence, as a result of pressure or pressure and shear. Epidemiological data show that pressure ulcers represent a lifelong threat to people who have spinal cord injuries, with 15% to 30% of spinal cord injury patients having had pressure ulcers during their lifetime. Acute care rehabilitation data suggest that individuals with spinal cord injuries who have complete tetraplegia are at the highest risk of developing a pressure ulcer (53%), followed by those with complete paraplegia (39%), incomplete tetraplegia (29%), and incomplete paraplegia (18%).

Pressure ulcers account for 24% of morbidity during the rehabilitation period, and the likelihood that patients will experience pressure ulcers increases over time. In 2007 it was estimated that the cost of treating pressure ulcers in the United States was $9 billion to $11 billion a year, with approximately $70,000 worth of expenses per hospitalization. In addition to the economic effect, chronic pressure ulcers represent a significant source of morbidity and mortality in people who have spinal cord injuries.

Risk factors for developing pressure ulcers fall into 2 groups: intrinsic and extrinsic. Intrinsic factors include age, limited mobility, inability to reposition independently, and loss of sensation. The loss of sensation contributes to tissue injury and subsequent ischemia. Extrinsic factors include pressure, humidity, friction, and shear force. The normal capillary filling pressure is 32 mm Hg, and patients who change positions infrequently or who are bedridden for extended periods greatly exceed the normal capillary filling pressure, thereby promoting skin ulcer formation. Lack of bowel and bladder control also contributes to risk because the addition of moisture and bacteria can promote skin breakdown. Transferring a patient from bed to stretcher can cause friction and shearing damage to the outer layers of the skin. Patients at particular risk are those who keep the head of the bed elevated at 30° or more.

Capillary loops in the skin are vertically oriented, so when lateral forces are applied (shear), capillary loops are easily kinked, which results in dermal ischemia and necrosis. The predominant location of pressure sores is the lower portion of the body, particularly the sacral region and the heels. Other common locations for pressure sores are bony structures that bear weight, such as the elbows, ankles, ischia, knees, scapulas, shoulders, and occiput.

As the number of people who have spinal cord injuries increases in this country, more caregivers will need the skills to assess and treat pressure ulcers. Measuring pressure ulcers can be time consuming and requires descriptions of the wound depth, circumference, length, undermining, and tunneling. Undermining can occur around the edges of the wound and is a space between the intact skin and the wound bed. It can appear as a “roof” over part of the wound. Undermining can occur from shear forces combined with sustained pressure on the wound. Tunneling occurs when a channel is formed through subcutaneous tissue or muscle to another part of the wound. Clinicians measure tunneling and undermining in centimeters by gently probing the wound with a graduated device as far as it will go without exerting undue force. The position and orientation of a tunnel is documented using a clock face, with 12 o’clock representing the patient’s head and 6 o’clock representing the patient’s feet. A variety of scales to measure and monitor...
pressure wounds are available. The goal of these tools is to provide objective and quantifying data that can be used to optimize the treatment and care of the wounds, but currently no international standard exists for measuring and classifying pressure ulcers.

A 2010 study in the Netherlands evaluated 3 different scales for efficiency: the Pressure Sore Status Tool, the Pressure Ulcer Scale for Healing, and the Sessing scale. According to the study’s authors, the most comprehensive is the Pressure Sore Status Tool scale, which consists of 13 domains in 5 categories. The Pressure Ulcer Scale for Healing scale assesses 3 domains and categorizes the surface of the wound by multiplying the longest length by the longest width while considering other wound attributes such as the amount of exudate and tissue type. The Sessing scale consists of 7 categories but does not include measurements. The authors reported advantages and disadvantages to each method. Specialists at the Long Beach Veterans Administration Medical Center in Long Beach, California, developed and implemented the Pressure Ulcer Monitoring Tool to collect data about wounds to design optimal clinical care, according to Asanza (written communication, October 2012).

The National Pressure Ulcer Advisory Panel is a recognized leader in the United States for promoting awareness of pressure ulcers. The staging system this organization endorses is the Shea system developed in 1975 (see Table 3).

Management of pressure ulcers requires a multidisciplinary team taking a holistic approach to include the patient’s biologic, psychological, and social needs to optimize conditions for healing. Four components to pressure ulcer management include prevention, correction of causative factors, debridement, and moist wound healing.

One of the tools used to prevent formation of pressure ulcers is the Braden scale. Components of this assessment tool include:

- Sensory perception.
- Skin moisture.
- Physical activity.
- Nutritional intake.
- Friction and shear.
- The patient’s ability to reposition.

Numeric values are assigned to determine the risk factor. The Braden scale score determines the level of risk. Interventions can be applied to alleviate and minimize the risk conditions based on the scores. For example, if an assessor rates a patient as “unable to reposition,” the caregiver might implement an intervention to turn the patient every 2 hours. Treatment of the pressure ulcer might include use of moist dressings, application of vacuum wound devices, surgical debridement, intravenous antibiotic therapy, use of biologics, and more. One study suggested that the use of medical-grade honey in the treatment of pressure ulcers could show some promise and that its use warrants further research.

Despite the fact that many people with spinal cord injuries receive good care, pressure ulcers remain a fact of life for them. Causes and consequences are numerous, and the sequelae are complex. Personnel in the radiology department should be cognizant of patients’ inability to reposition and should monitor them frequently. Pressure relief interventions such as using cushions on the examination table and frequent repositioning should be implemented.

Respiratory Considerations

Immediately following spinal cord injury, respiratory failure can occur as a result of complete or partial respiratory muscle paralysis, fatigue of the remaining intact musculature, or because of other pleuropulmonary pathology. After patients are stabilized, respiratory complications including pneumonia continue to be one of the leading causes of death for individuals with spinal cord injuries. Loss of lung volume is related to loss of respiratory muscle innervation for individuals with complete tetraplegia.

The severity of respiratory impairment is directly related to the level of the injury. For example, injuries to the nerves high in the cervical cord, from C1 through C4, are associated with the greatest respiratory muscle dysfunction, and patients with injury at C1 and C2 cannot maintain effective spontaneous ventilation. Injuries to the nerves in the lower cervical cord from C5 through C8 affect the intercostal, parasternal, scalene,
**Table 3**

<table>
<thead>
<tr>
<th>Category</th>
<th>Extent of Injury</th>
<th>Function</th>
</tr>
</thead>
</table>
| **Stage I**                  |                                                                                  | *Intact skin with nonblanchable redness of a localized area usually over a bony prominence.*  
  Nonblanchable erythema       |                                                                                  | *Darksly pigmented skin might not have visible blanching; its color might differ from the surrounding area.*  
  The area might be painful, firm, soft, and warmer or cooler than the adjacent tissue.*  
  Category I might be difficult to detect in individuals with dark skin tones.*  
  May indicate "at risk" persons.  |
| **Stage II**                 |                                                                                  | *Loss of dermis presenting as a shallow open ulcer with a red or pink wound bed, without slough.*  
  Partial thickness            |                                                                                  | *May present as an intact or ruptured serum-filled or sero-sanginious filled blister.*  
  Presents as a shiny or dry shallow ulcer without slough or bruising.*  
  This category should not be used to describe skin tears, tape burns, incontinence-associated dermatitis, maceration, or excoriation.  |
| **Stage III**                |                                                                                  | *Full thickness tissue loss.*  
  Full thickness skin loss     |                                                                                  | *Subcutaneous fat might be visible, but bone, tendon, or muscle is not exposed.*  
  Slough might be present but does not obscure the depth of tissue loss.*  
  Might include undermining and tunneling.*  
  The depth of a Stage III pressure ulcer varies by anatomical location.*  
  The bridge of the nose, ear, occiput, and malleolus do not have subcutaneous (adipose) tissue, and Stage III ulcers can be shallow.*  
  In contrast, areas of significant adiposity can develop extremely deep Stage III pressure ulcers.*  
  Bone or tendon is not visible or directly palpable.  |
| **Stage IV**                 |                                                                                  | *Full thickness tissue loss with exposed bone, tendon, or muscle.*  
  Full thickness tissue loss   |                                                                                  | *Slough or eschar might be present.*  
  Often includes undermining and tunneling.*  
  The depth of a Stage IV pressure ulcer varies by anatomical location.*  
  The bridge of the nose, ear, occiput, and malleolus do not have subcutaneous (adipose) tissue, and these ulcers can be shallow.*  
  Stage IV ulcers can extend into muscle and/or supporting structures (eg, fascia, tendon, or joint capsule), making osteomyelitis or osteitis likely to occur.*  
  Exposed bone or muscle is visible or directly palpable.  |
| Unstageable/ Unclassified    |                                                                                  | *Full thickness tissue loss in which actual depth of the ulcer is completely obscured by slough (yellow, tan, gray, green, or brown) and/or eschar (tan, brown, or black) in the wound bed.*  
  Full thickness skin or tissue loss depth unknown |                                                                                  | *Until enough slough and/or eschar are removed to expose the base of the wound, the true depth cannot be determined; but it will be either a Stage III or IV.*  
  Stable (ie, dry, adherent, intact without erythema or fluctuance) eschar on the heels serves as "the body’s natural (biological) cover" and should not be removed.  |
| Suspected                    |                                                                                  | *Purple or maroon localized area of discolored intact skin or blood-filled blister due to damage of underlying soft tissue from pressure and/or shear.*  
  Deep Tissue Injury           |                                                                                  | *The area might be preceded by tissue that is painful, firm, mushy, boggy, or warmer or cooler than adjacent tissue.*  
  Deep tissue injury might be difficult to detect in individuals with dark skin tones.*  
  Evolution might include a thin blister over a dark wound bed. The wound might further evolve and become covered by thin eschar.  |


*Bruising indicates deep tissue injury.*
and abdominal muscles but render the diaphragm, trapezi, sternocleidomastoid, and clavicular portion of the pectoralis major muscles intact, which can lead to diminished cough capacity. When these patients contract an upper respiratory infection, they have difficulty clearing airway secretions because of the inability to produce a strong cough.

Signs of respiratory distress could include coughing, poor chest wall expansion, rales or rhonchi, pallor, cyanosis, tachycardia, paradoxic movement of the chest wall, increased or labored accessory muscle use, agitation, and panic. Registered nurses or respiratory therapy personnel should be available to clear respiratory secretions for patients undergoing examinations or procedures when indicated.

**Additional Complications**

Additional complications of spinal cord injuries are precipitated by 3 subsequent phenomena that occur below the level of injury:

- A reduction in overall sympathetic activity.
- Morphological changes in sympathetic preganglionic neurons.
- Peripheral alpha-adrenoceptor hyper-responsiveness.

Moreover, cardiovascular disease is one of the top causes of morbidity and mortality in patients with spinal cord injuries. Lack of exercise, decreased muscle mass, and a host of metabolic syndrome type conditions contribute to this risk. Cases of silent myocardial ischemia have occurred during episodes of autonomic dysreflexia. Loss of sensory input from the myocardium to the supraspinal structures places patients with spinal cord injuries at risk for asymptomatic myocardial ischemia. During an episode of autonomic dysreflexia, there is an increase in the visceral sympathetic activity with associated coronary artery constriction, which can lead to myocardial ischemia, even if the patient does not have preexisting coronary artery disease.

Neurogenic shock is one way that autonomic nervous system dysfunction is manifested following a spinal cord injury. Neurogenic shock is a life-threatening decrease in blood pressure resulting from a sudden loss of signals from the sympathetic nervous system after a spinal cord or brain injury. Neurogenic shock most likely occurs because of an imbalance in autonomic control from intact parasympathetic stimuli via the vagal nerve and a loss of sympathetic tone because of disruption in the supraspinal control center.

Reversible cerebral vasoconstriction syndrome also has been associated with autonomic dysreflexia and is characterized by the sudden onset of severe headache, which might include neurological deficits, and reversible narrowing of the vasculature of the Circle of Willis and its associated branches. It occurs most commonly in women with spinal cord injuries from 20 to 50 years of age.

**Pediatric Patients**

Approximately 5% of spinal cord injuries in North America occur in children 15 years old or younger. Spinal cord injuries in boys are more common during adolescence, but incidence is equal between girls and boys younger than 5 years of age. Motor vehicle accidents cause most spinal cord injuries in children and adolescents, but violence accounts for large numbers of injuries in pediatric patients. Children have a higher risk of spinal cord injury from seatbelts and abuse. They also are more likely to have spinal cord injuries without radiologic abnormalities. Conventional radiographs, computed tomography (CT), and dynamic flexion and extension studies can appear normal in more than half of children who have spinal cord injuries that show no radiologic abnormalities. This increases to an incidence of 64% in children younger than 5 years of age who have spinal cord injuries.

Many of the events that cause spinal cord injury in pediatric patients are extremely traumatic and could put these patients and their families at risk for posttraumatic stress disorder (PTSD). Boyer et al stated 3 reasons children who have a spinal cord injury during childhood or adolescence are at an increased risk for PTSD:

- The injury usually is caused by a traumatic event.
- The acquisition of the injury might indicate a greater severity of that traumatic event.
- The injury represents a life-changing and, at times, life-threatening medical condition.

Adults with pediatric-onset spinal cord injury have unique medical complications and risk having other sequelae. Because pediatric patients have a longer life
span than patients whose spinal cord injury occurred during adulthood, they might have a heightened risk of pressure ulcers. In addition, sudden onset of spinal cord injury in school-aged children compels them to return to their earlier dependence on their parents, thereby disrupting the typical trajectory of increasing autonomy that is part of the developmental process. Therefore, one of the primary objectives of the pediatric rehabilitative process is to facilitate a positive adjustment to adulthood. Studies have demonstrated a negative relationship among medical complications, life satisfaction, jobs and income, and independent living in adults with pediatric-onset spinal cord injuries.

**Psychosocial and Sexual Considerations**

A number of studies have measured subjective well-being and other quality-of-life issues in people who have spinal cord injuries. Researchers found it difficult to distinguish between a temporary depressed mood and a persistent adjustment disorder immediately after the patient’s initial injury. People with spinal cord injuries tend to report higher levels of distress and a lower overall life satisfaction than the general population. This is not to say that all of these people report unhappiness; many have adapted well.

Assistive technology such as advanced mobility devices and technology that allows people with spinal cord injuries to more effectively interact with the world around them contributes to better rehabilitative outcomes. Spinal cord medicine professionals have organized and are sharing data at a global level to promote awareness and add to the spinal cord injury body of knowledge. The State of the Science Conference in Spinal Cord Injury Rehabilitation 2011 represented an international multidisciplinary team that focused on establishing a long-term research agenda for spinal cord injury medicine.

A European study conducted by Kennedy et al in 2006 focused on unmet needs of individuals with spinal cord injuries in the United Kingdom, Germany, Austria, and Switzerland. The needs that participants rated as highly met were necessities relating to skin management, wheelchair use, and accommodations for mobility. The unmet needs the participants identified most were gainful occupation, sexual activity, and pain relief. Lack of mobility, social isolation, and diminished self-esteem, combined with bowel and bladder management issues, contribute to depression and a feeling of isolation in some people living with spinal cord injuries.

Spinal cord injuries have significant psychological and physical arousal issues on both men and women. Many people with spinal cord injuries report having difficulty becoming psychologically and physically aroused, which contributes to an altered sense of the individual’s sexual self. Erectile dysfunction has been reported as a serious determinant of psychological distress in men. Treatment of erectile dysfunction with sildenafil has been reported to significantly improve the quality of life for men with erectile dysfunction caused by spinal cord injury. Nevertheless, bowel and bladder incontinence and the risk of autonomic dysreflexia also have been reported to negatively affect sexual activity and intercourse. Researchers continue to work on developing methods and strategies for people with spinal cord injuries to develop forms of sexual pleasure and activity so they can return to the most optimal lifestyle possible.

**Pain Management**

People who have spinal cord injuries list pain among the top most disabling conditions secondary to their injury. Some patients experience relentless and unremitting levels of pain despite best efforts to alleviate it. One study suggested that individuals report neuropathic pain from spinal cord injury is worse at night than at other times of the day. Neuropathic pain occurs when nerve fibers are damaged and send incorrect signals to pain centers. These patients must learn to adapt to life with some degree of chronic pain.

The International Spinal Cord Injury Pain classification was established to create a method for classifying pain reported by people with spinal cord injuries. The classification system was established with the premise that pain must be classified properly before it can be treated effectively. The system is comprehensive enough to be used by both experienced and inexperienced clinicians as well as clinical researchers. Its design incorporates pain that is directly related to spinal cord injury, along with pain not mechanically related to the spinal cord injury.
The system examines pain relative to 3 tiers: the pain type, subtype, and the primary source or pathology.71 The International Spinal Cord Injury Pain classification system comprises assessments for nociceptive pain, which includes musculoskeletal, visceral, and other nociceptive pain. The system also includes neuropathic pain with an assessment of the level of pain relative to the spinal cord injury location and a category for other pain including fibromyalgia, complex regional pain syndrome type I, interstitial cystitis, and irritable bowel syndrome. The system also includes a category for unknown pain. Studies were conducted with clinicians to validate the reliability of the International Spinal Cord Injury Pain classification tool. Results showed that with training, clinicians achieved satisfactory results but further testing is indicated, including applying the tool to individuals who have pain from spinal cord injury.72

Chronic pain that impairs quality of life in spinal cord injury patients has led to a substantial increase in research directed at managing pain related to the condition.73 Several studies have examined how pain affects the overall quality of life for these patients, the use of a variety of treatments for people who have chronic pain following spinal cord injury, and patients’ ability to adjust to chronic pain.68,74-80

Management of chronic pain is an important attribute of long-term quality-of-life indicators.73 Pain treatment therapies consist of the use of pain medications, complementary therapies such as acupuncture and massage, external Qigong therapy, physical therapy, and more. In 2010, authors Norrbrink and Lundeberg reported that neuropathic pain after spinal cord injury only narrowly responded to most interventions but that both acupuncture and massage might relieve some neuropathic pain in individuals with spinal cord injuries.81 Care plans should effectively address comorbid pain and depression after a spinal cord injury because the 2 conditions are linked in this patient population.76

**Medical Imaging**

Obtaining an accurate assessment of initial damage to the spinal cord is imperative so physicians can implement the optimal neuroprotective intervention. Conventional radiography is an inexpensive and beneficial tool to demonstrate vertebral misalignment or fracture or foreign body fragments lodged in the spine, but it is not as specific as magnetic resonance (MR) imaging or CT for demonstrating detailed information about the spinal cord, disk spaces, and bleeding.

Conventional MR imaging is currently considered the best modality for evaluating the extent of injury in patients with traumatic spinal cord injuries.82 Cord compression, edema, and hemorrhage can easily be identified using standard clinical MR sequences (see Figure 7).

The presence of large intraparenchymal hemorrhages has been shown to be an indicator of poor outcome following traumatic spinal cord injury.82 Unfortunately, conventional MR does not sufficiently display the integrity of...
the long white-matter tracts responsible for the majority of the deficits following a traumatic spinal cord injury. However, diffusion-weighted imaging is reported to be more effective and yield a higher diagnostic value than conventional MR.82

T2-weighted and diffusion-weighted imaging were shown to have comparable detection rates for spinal cord damage in patients with spinal cord trauma within 24 hours of injury.82 Pouw et al stated that spinal cord white matter tracts are well organized in the craniocaudal direction, and diffusion is anisotropically oriented (ie, differing from the direction of the white matter tracts), with a higher apparent diffusion coefficient along the fibers than transversely. Therefore, diffusion-weighted imaging is useful to evaluate the integrity of the white matter tracts in the spinal cord and might be able to provide more information than conventional MR techniques.82

CT is an excellent modality for detecting bone fractures, bleeding, and spinal stenosis, but it is not optimal for imaging of the spinal cord or for identifying ligament injury associated with an unstable spine.11

**Patient Care Considerations in Radiology**

Patients who have spinal cord injuries have unique needs that require interventions designed to promote an optimal and safe environment during a diagnostic imaging examination. Radiologic technologists should recognize these needs so they can respond competently and compassionately. For example, the department should have transport stretchers that are height-adjustable to allow safe transfers of patients to and from the examination tables. Other concerns include the prevention of pressure ulcers, the patient’s bowel and bladder management, pain control, recognition of early signs and symptoms of autonomic dysreflexia, and, in some cases, pulmonary and respiratory support. Technologists should be equipped to intervene promptly if signs and symptoms of autonomic dysreflexia develop during a procedure. They should consult with nurses and clinicians to identify specific needs a patient might have before beginning an examination or procedure. Before performing a medical imaging procedure, the technologist should determine whether the patient:

- Requires bowel care before the examination.
- Has any existing wounds.
- Can tolerate the pressure from the examination table.
- Has a history of autonomic dysreflexia.
- Requires specific positioning aids.
- Requires manual ventilation.
- Has adaptive equipment for communication.
- Requires administration of an anxiolytic agent.

Patients who have sustained a spinal cord injury as a result of a traumatic battlefield injury might suffer from PTSD. These patients might need special assistance while undergoing procedures that involve CT or MR scanners.

Because pain is one of the most difficult chronic conditions that people with spinal cord injuries face, technologists should assess patients in their care periodically for pain. Prompt intervention to mediate the pain by repositioning, the use of pharmacological agents, or other comfort measures should occur if the patient reports a pain level higher than a 5 on a scale of 1 to 10. Radiologic technologists should not hesitate to contact trained spinal cord injury caregivers before receiving the patient in the department. Patients with spinal cord injuries typically understand that they have unique care needs, and many patients appreciate the willingness of other health care providers to participate in an optimal care plan.

**Advances in Treatment**

Despite recent advances in spinal cord injury medicine, research and development needs to continue. Advances in adaptive technology are promising, but they do not address the biological need to regenerate the central nervous system.

In January 2013, doctors at the Miami Project to Cure Paralysis, part of the University of Miami Miller School of Medicine, announced the first phase of the first clinical trial to transplant a patient’s own Schwann cells, the cells that myelinate axons.83 According to neurosurgeon Barth Green, MD:

*This historic clinical trial represents a giant step forward in a field of medicine where each tangible step has tremendous value. This trial, and these first patients in this trial specifically, are extremely important to our mission of curing paralysis.*83
A study in India examined the use of autologous mesenchymal stem cells to treat patients with chronic spinal cord injury. Two patients in that study reported limited improvement in pinprick sensation below the level of injury.

Some anti-inflammatory medications such as rolipram show promise in regenerating axonal growth by stimulating central nervous system axons through inhibition of amino acid toxicity and resultant cell death after initial injury. Monoclonal antibodies such as Nogo-A are being studied because of their ability to block proteins that inhibit the regeneration of axons after an injury. Cethrin is a protein that stops activation of Rho, another protein that blocks axonal regeneration and has been tested in clinical trials. Histone deacetylases are a class of compounds that regulate gene expression and can limit cell regeneration after traumatic spinal cord injury. Preclinical studies are underway that could inhibit histone deacetylase activity and thereby allow axons to regenerate in spinal cord injury regions.

Other promising advances include chondroitinase ABC to clear away tangled and damaged proteins and sugars around the injury site, implanted matrices that allow the axons to bridge over the lesion, cell replacement using stem cells and glial cells, use of human oligodendrocyte progenitor cells to promote myelination, transplantation of bone marrow stromal cells, and use of nasal olfactory ensheathing cells to replace and encourage remyelination of the lesion site. More futuristic approaches include brain-computer interfaces, which use technology implanted into the damaged nerve system to reestablish a link from the brain to the muscles, and neural implanted impulse technology that coordinates movements to prosthetic limbs.

In a recent Chinese study, rodents with spinal cord injuries were vaccinated with dendritic cells pulsed with spinal cord homogenates. Researchers reported that the implanted dendritic cells pulsed with homogenate protein from the spinal cord showed promise relative to functional recovery and neural preservation in mice. They found that this procedure improved functional recovery and decreased the area of cysts and the density of glial scarring.

Research methods and clinical trials are varied, and many show promise. However, more research in neuroprotection, cell regeneration, cell replacement, and retraining central nervous system circuits will help advance spinal cord medicine toward a cure for paralysis. Until there is a cure, radiologic technologists and other health care professionals should be equipped to provide the best care possible for these patients.

**Conclusion**

Patients with spinal cord injuries arrive at the radiology department with a variety of unique medical and psychological needs. Awareness of the patients’ specific care considerations should be part of the core competency set for department personnel. For example, prompt recognition of autonomic dysreflexia leads to rapid intervention and can avoid a life-threatening episode. Radiology personnel should collaborate with the interdisciplinary care team before conducting any diagnostic examination or interventional procedure on a patient who has a new or chronic spinal cord injury. Knowledge of these patients’ special needs and compassionate application of care considerations will help create a safe and comfortable environment for the individual who has a spinal cord injury.

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Reprint requests may be mailed to the American Society of Radiologic Technologists, Communications Department,
References


Care Considerations for Patients With Spinal Cord Injuries

1. The average age of patients at the time of a spinal cord injury is _______ years.
   a. 15  
   b. 24  
   c. 36  
   d. 41

2. The collection of nerves located at the end of the spinal cord is called the conus _______.
   a. equinas  
   b. medullaris  
   c. terminale  
   d. foramina

3. Motor neurons conduct impulses:
   a. from the central nervous system to the muscles or glands. 
   b. from receptors in the skin. 
   c. from skeletal muscles and joints. 
   d. from internal organs.

4. _______ are branching projections that provide a larger surface area to pass a chemical signal to many target cells simultaneously.
   a. Axons  
   b. Dendrites  
   c. Interneurons  
   d. Sensory ganglia

5. Sensory innervation to which of the following controls the sphincters and the parasympathetic impulses to control the bladder and the lower bowel?
   a. thoracic region  
   b. pelvic articulate  
   c. coccygeal region  
   d. saddle area

*Your answer sheet for this Directed Reading must be received in the ASRT office on or before this date.
6. According to the article, the number of spinal cord injuries from which of the following have increased?
   a. football
   b. skiing
   c. motor vehicle accidents
   d. violence

7. Which of the following populations has the lowest incident rates for spinal cord injury?
   a. people aged 16 to 30 years.
   b. men
   c. children
   d. women

8. Spinal shock results in:
   1. complete paralysis.
   2. loss of reflexes.
   3. loss of sensation.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

9. According to the American Spinal Injury Association Impairment Scale, a complete injury represents the absence of sensory and motor function in the lowest sacral segments.
   a. true
   b. false

10. Paraplegia usually results from an injury in which of the following spine segments?
    1. cervical
    2. thoracic
    3. lumbar
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

11. Injuries that occur above the level of ______ can result in immediate, life-threatening cardiovascular complications.
    a. S5
    b. L5
    c. T5
    d. C5

12. Autonomic dysreflexia is a potentially life-threatening medical emergency that seems to be most common in patients:
    a. who are young and have lived with the injury for years.
    b. who are older with new traumatic injuries.
    c. with injuries below the level of T10.
    d. with bradycardia.

13. Which of the following are signs and symptoms of autonomic dysreflexia?
    1. sudden increase in blood pressure
    2. reflex bradycardia
    3. sweating
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3
14. The most common cause of autonomic dysreflexia is:
   a. distension of the bladder.
   b. fecal impaction.
   c. pressure sores.
   d. hemorrhoids.

15. According to the article, the first procedure in treating a patient with autonomic dysreflexia is to:
   a. loosen or remove any restrictive clothing to relieve noxious stimuli.
   b. sit the patient upright to induce orthostatic hypotension to counter the hypertension.
   c. check for fecal impaction.
   d. administer an antihypertensive agent.

16. If a radiologic technologist suspects a patient is showing signs of autonomic dysreflexia, he or she should monitor vital signs with a focus on:
   a. heart rate.
   b. respiration.
   c. blood pressure.
   d. temperature.

17. According to the article, which type of catheter has led to remarkable improvements in problems associated with bladder incontinence?
   a. an indwelling catheter
   b. suprapubic catheterization
   c. clean intermittent catheterization
   d. filiform catheterization

18. Prior to 1940, people with spinal cord injuries typically died from:
   a. respiratory issues.
   b. urinary tract infections.
   c. kidney failure.
   d. pressure ulcers and resultant osteomyelitis.

19. According to a study at the Long Beach Veterans Administration Medical Center, bladder cancer was listed as one of the most severe complications of:
   a. an indwelling catheter.
   b. suprapubic catheterization.
   c. clean intermittent catheterization.
   d. filiform catheterization.

20. According to a 2009 study by Coggrave et al, which of the following did respondents list as the number-one contributor to injury-related impairments?
   a. bladder dysfunction
   b. bowel dysfunction
   c. pressure ulcers
   d. risk of autonomic dysreflexia

21. Patients with spinal cord injuries of which level are at the highest risk of developing pressure ulcers?
   a. complete tetraplegia
   b. complete paraplegia
   c. incomplete tetraplegia
   d. incomplete paraplegia

22. Intrinsic risk factors related to pressure ulcers include:
   1. friction.
   2. age.
   3. limited mobility.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

continued on next page
23. According to the National Pressure Ulcer Advisory Panel staging system, a stage II pressure ulcer is described as:
   a. a nonblanchable redness with intact skin.
   b. a partial thickness wound with a loss of the dermis presenting as a shallow open ulcer.
   c. a full thickness wound with tissue loss and possible visible fat but no visible bone, muscle, or tendon.
   d. full thickness tissue loss.

24. Radiologic technologists can help prevent and manage pressure ulcers by using cushions on the examination table and frequently repositioning patients.
   a. true
   b. false

25. Patients with nerve injury at ______ cannot maintain effective spontaneous ventilation.
   a. C1 through C2
   b. C3 through C4
   c. C5 through C6
   d. C7 through C8

26. According to the article, cardiovascular disease is one of the leading causes of morbidity and mortality in individuals with spinal cord injuries because of:
   1. lack of exercise.
   2. decreased muscle mass.
   3. diet.

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

27. Kennedy et al found that the main unmet needs of people with spinal cord injuries are gainful occupation, sexual activity, and:
   a. skin management.
   b. wheelchair accommodations.
   c. pain relief.
   d. treatment for posttraumatic stress disorder.

28. According to the article, which of the following is considered the best modality for evaluating the extent of injury in patients with traumatic spinal cord injuries?
   a. computed tomography
   b. conventional magnetic resonance imaging
   c. plain radiographs
   d. diffusion-weighted magnetic resonance imaging

29. Before performing a medical imaging procedure, the radiologic technologist should determine whether the patient:
   1. requires bowel care.
   2. can tolerate pressure from the examination table.
   3. has a history of autonomic dysreflexia.

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

30. The clinical trial by the Miami Project to Cure Paralysis is the first trial of transplanting which type of a patient’s own cells?
   a. Schwann
   b. mesenchymal
   c. Dexter
   d. filiform