Literature Review

OVERVIEW OF BROWN-SEQUARD SYNDROME

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Received: 03-30-2024; Accepted: 04-09-2024; Published: 04-15-2024.

Abstract. A neurologic syndrome called Brown-Séquard syndrome is brought on by spinal cord hemisection. On the side of the body, ipsilateral to the lesion, it presents as weakness or paralysis, proprioceptive abnormalities, and loss of pain and temperature perception. Brown-Séquard syndrome is an incomplete spinal cord syndrome with a range of severity in its clinical presentation.

One of the most intricate and fascinating areas of the nervous system to study is the spinal cord. Its overwhelming clinical presentation, development problems, lesions, and intricate connections call for a deeper comprehension of its anatomical and physiological makeup.

Like the brain, the extremely fragile and sensitive spinal cord is well-protected by the robust bony cage comprising the vertebral arch and vertebral bodies. Together, they create the spinal hollow, or long spinal column, which houses the spinal cord. Millions of neurons reside in the spinal cord, and their bundled fibers run as ascending or descending tracts. Thirty-one pairs of spinal nerves, primarily supplying the trunk and limbs, emerge from the spinal cord. These are mixed spinal nerves with a motor component that assists in controlling the trunk and voluntary muscles in all limbs. Additionally, they have a sensory component that aids in taking in the sensory data from these regions. Therefore, for a better understanding of the clinical presentation and its pathology in any spinal cord lesion, it is imperative to grasp the fundamentals of anatomy.

In this short review, we have discussed the symptoms, management, and prevention of brown syndrome.

Keywords: Brown-Séquard syndrome, spinal cord injury, brain, sensory function, motor function.

INTRODUCTION Brown-Séquard syndrome (BSS) was named after the scientist Charles-Édouard Brown-Séquard, who originally characterized it in 1849 [1].

Brown-Séquard syndrome is a rare neurological disorder in which spinal cord injury generates muscle weakness or paralysis on one side of the body and sensory loss on the opposite side. There are cases when damage affects only one side of a spinal cord in a specific place [2]. In these cases, Brown-Séquard syndrome is classified as an incomplete spinal cord injury (SCI) [3]. This means there is some sensory function, motor function, or a mix of the two below the point where the lesion happened on a patient spine. A full SCI causes the loss of all sensory and voluntary motor capabilities beneath the level of the injury [4].

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EPIDEMIOLOGY: BSS is a rare illness, with approximately 11,000 new cases reported annually in the United States. They account for around 4% of all spinal cord injuries caused by trauma. According to the National Institute of Neurological Disorders and Stroke, the condition's rarity hinders research and treatment development [5,6].

RISK FACTORS: Spinal cord injuries can occur at any age. However, several circumstances enhance the likelihood of incurring this type of injury.

The National Spinal Cord Injury Statistical Center reports that,

- Spinal cord injuries occur at an average age of 43 years.
- Males make up 78% of new spinal cord injury cases.
- Nearly 40% of spinal cord injuries are caused by vehicle incidents, followed by falls (Figure 1).

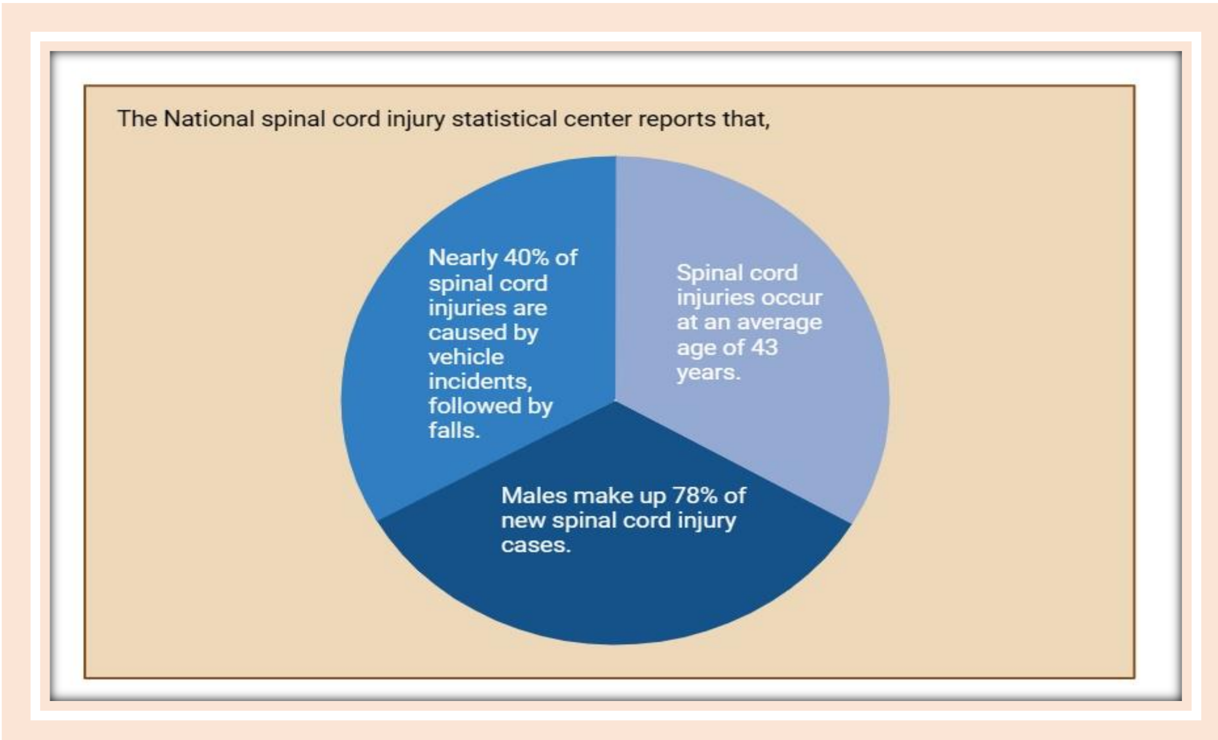

Figure 1. The National Spinal Cord Injury Statistical Center reports (https://www.nscisc.uab.edu/Public/AR2022_public%20version.pdf).

According to the American Association of Neurological Surgeons:

- Motor vehicle accidents are the most common cause of spinal cord damage among young individuals.
- Falls are the greatest cause of spinal cord damage in individuals over 65 years.

Males account for up to 90% of sports-related spinal cord injuries [7].

ANATOMY OF SPINAL CORD.

The spinal cord is one of the nervous system's most intricate yet interesting aspects. Its intricate connections, developmental flaws, lesions, and clinical presentation are extremely challenging, requiring a greater understanding of its anatomical and physiological features.

The spinal cord is an essential component of the central nervous system, which is cylindrical and elongated in shape. It is one of the most vital components of the spinal canal. It appears as an extension of the lowest region of the brain stem, known as the medulla oblongata. It starts at the first cervical vertebra and finishes at the first lumbar vertebra in an adult [8].

Like the brain, the highly delicate and sensitive spinal cord is well-protected by a robust bony cage made up of the vertebral arch and body. Together, they form a lengthy spinal column (spinal cavity) that contains the spinal cord.

The spinal cord contains millions of neurons, and their bundled fibers run as either ascending or descending tracts [9].

Three meninges—the dura mater, arachnoid mater, and pia mater—entirely cover the spinal cord. Cerebrospinal fluid (CSF) in the subarachnoid space provides additional protection and cushioning.

The spinal cord gives rise to 31 pairs of spinal nerves, mostly supplying the trunk and limbs. These spinal nerves are mixed nerves with a motor component that controls all the voluntary muscles in the limbs and trunk [10].

STRUCTURE AND FUNCTION.

External Features. The spinal cord is a long cylindrical extension of the central nervous system located within the vertebral column's hollow. It measures roughly 42.3 cm in length in males and 38.9 cm in females [11].

The spinal cord is symmetrical, with fusiform enlargements in the cervical and lumbosacral regions. The highest transverse diameter occurs at the C5 section [4]. Similarly, the lower thoracolumbar expansion creates the lumbosacral plexus, a network of nerves that supplies the lower limb muscles [12].

The lowermost section of the spinal cord tapers in a cone-like shape and is known as the conus medullaris. An extension of the pia mater, known as the filum terminal, descends from the apex of the conus medullaris and attaches to the posterior surface of the coccyx (Figures 2 &3).

Cellular Level. The spinal cord comprises grey and white matter, which appears as an H-shaped pattern in a cross-section.

The cell bodies of sensory and motor neurons, interneurons, and neuropils—primarily unmyelinated axons and neuroglia cells—make up the grey matter. The interconnected fiber tracts that make up the white matter, on the other hand, are mainly myelinated motor and sensory axons [13].

Grey Matter. The grey matter is shown in the center as an H (butterfly) shaped mass in a transverse spinal cord segment. The grey matter is divided into two parts on each half of the cord: a bigger ventral mass (anterior/ventral horn) and an elongated dorsal grey column (posterior/dorsal horn) [14].

The central canal houses CSF and is bordered by ependymal cells. The grey matter is divided into ten laminae. Laminae I–VI makes up the posterior grey column.[6] Lamina VII is located in the middle region. At the same time, lamina VIII is confined to the medial part of the anterior grey column, and lamina IX occupies the lateral part of the anterior grey column. The area surrounding the central canal is known as lamina X [7]. Each of these laminae has distinct connections and functions [15,16].

White Matter. The white matter exists superficially around the grey matter. The dorsal (posterior) funiculus is formed on both sides by the medial white matter to the posterior grey column. The ventral (anterior) funiculus comprises white matter medial and ventral to the ventral

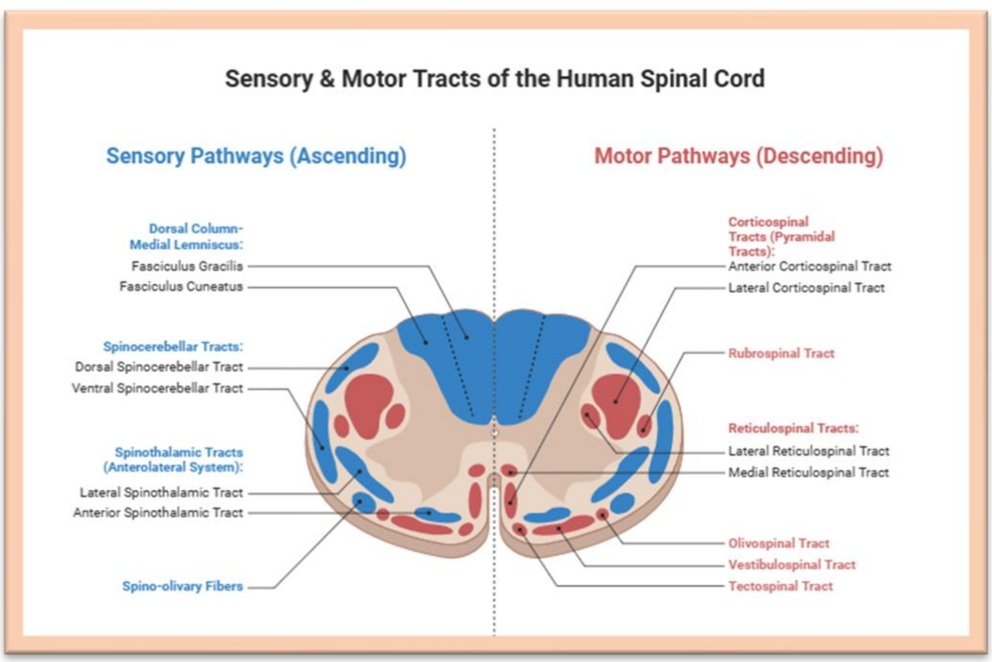

Figure 2. Sensory and Motor Tracts of the Human Spinal Cord (https://www.biorender.com/template/sensory-and-motor-spinal-tracts-of-the-human-spinal-cord) [63].

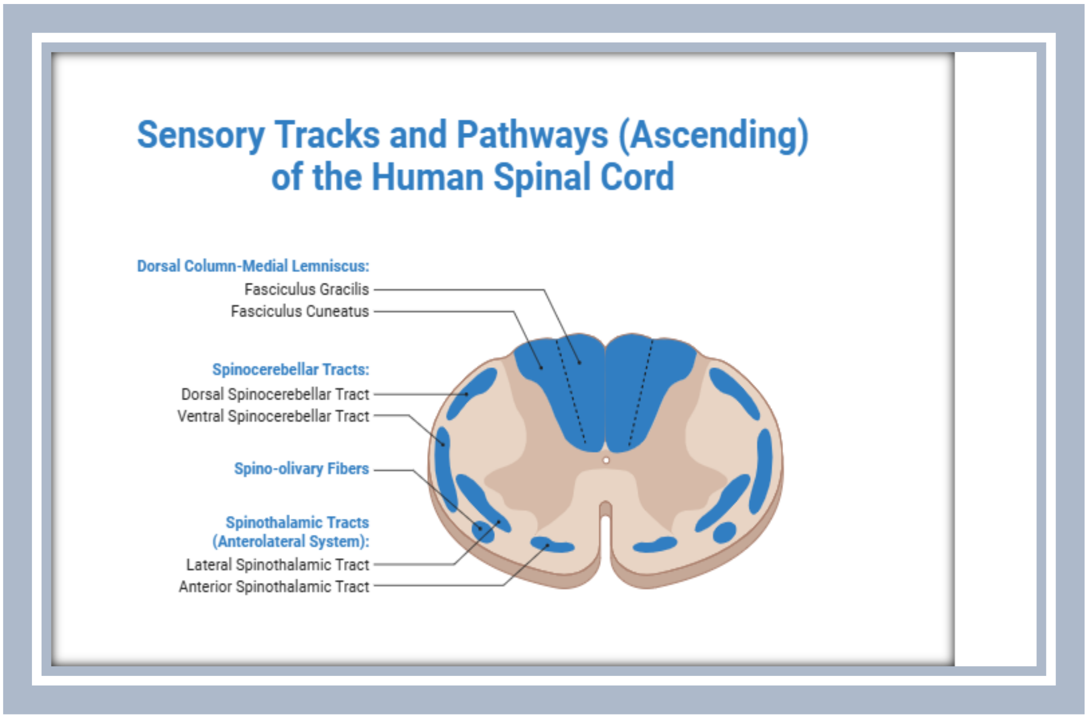

Figure 3. Sensory tracks and pathways (Ascending) of the human spinal cord [63].

(anterior) grey column. The white matter lateral to the anterior and posterior grey columns creates the lateral funiculus [17].

Ascending Tracts.

Doral column. The cuneate and gracile fasciculi comprise the dorsal funiculus and are located in the dorsal column. The dorsal column controls movement sense, conscious proprioception, two-point discrimination, and pressure and vibration sensation. The medial lemniscus is formed when the dorsal column decusses at the superior part of the medulla oblongata [18].

Lateral Spinothalamic Tract. The lateral spinothalamus carries information about temperature and pain. Two segments above the spinal cord entry, at the anterior commissure, is where the lateral spinothalamic tract decusses.

Anterior Spinothalamic Tract. It relays inaccurate touch and pressure signals. It discusses similar to the brainstem lateral thalamus [19].

Dorsal and Ventral Spinocerebellar Tract. The cerebellum receives sensory data related to unconscious proprioception from the dorsal and ventral spinocerebellar regions. The dorsal spinocerebellar tract decusses twice, making both tracts ipsilateral, whereas the ventral spinocerebellar tract does not decussate [20].

Descending Tracts.

Lateral and Anterior Corticospinal Tract. The conscious regulation of skeletal muscle is mediated via the anterior and lateral corticospinal areas. The inferior part of the medulla oblongata is where the majority of the lateral corticospinal tract fibers decussate. On the other hand, the anterior corticospinal tract decusses at the segmental level and descends ipsilaterally in the spinal cord. The anterior corticospinal tract innervates the proximal muscles of the trunk. In contrast, the contralateral muscles of the limbs are innervated by the lateral corticospinal tract, also known as the pyramidal tract.

Vestibulospinal Tract. Controls head position by transmitting information from the inner ear and adjusts muscle tone to preserve balance and posture. It is not the vestibulospinal tract that decusses.

Rubrospinal: contributes to the flexor and extensor muscle movements. The midbrain's red nuclei are the source of the rubrospinal tract, which decusses at the beginning of its course.

Reticulospinal: derives from the brainstem's reticular formation, which supports, regulates, and enhances the corticospinal tract. There is no decussation of the reticulospinal tract [21].

The spinal nerves are 31 pairs—8 pairs of cervical, 12 pairs of thoracic, five pairs of lumbar, five pairs of sacral, and one pair of coccygeal nerves [22].

The location of the injury also affects its kind. There are four sections to the spinal cord (Figure 4):

- The cervical spine (vertebrae C1–C8) has eight cervical nerve roots.
- The thoracic spine (vertebrae T1–T12).
- Lumbar spine (vertebrae L1-L5).
- Sacral spine (vertebrae S1–S5).

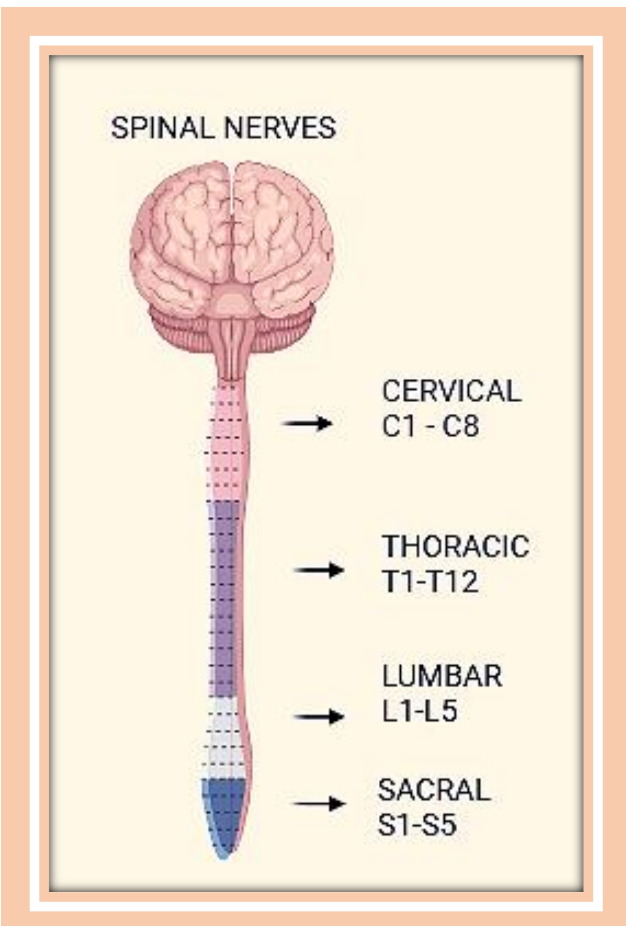

Figure 4. Spinal Nerve Image.

Cervical spinal injury. The cervical spine is the upper section of the spine containing the neck vertebrae. Cervical spine injuries are the most serious since they are closest to the brain and can impact the entire body [23].

Tetraplegia, often known as quadriplegia, is a condition in which the four limbs and the torso are completely or partially paralyzed due to a cervical spine injury [24,25].

Thoracic spinal injury. The thoracic spine encompasses the upper and middle back. A thoracic spine injury commonly affects the belly, legs, and lower back muscles. People who have had a thoracic spine injury may experience paraplegia, which is paralysis in certain regions of their trunk and legs. A person with paraplegia can still move their arms and hands [26,27].

Lumbar spinal injury. The lumbar spine is the spinal column's lowest main segment. The vertebrae in this portion are bigger because they bear more weight than those in other parts of the spine.

A person with a lumbar spine injury may lose function in the hips and legs, but they normally keep control of their upper body. Some patients who have sustained a lumbar spine injury may be able to walk with braces or use a wheelchair [28].

Sacral Spine Injury. The region just above the tailbone is called the sacral spine. The nerves that emerge from this section of the spinal cord control the hips, groin, and backs of the thighs.

A sacral spine injury may result in partial hip and leg function loss. Additionally, it might impair bowel and bladder control. Still, many persons who have suffered sacral spine damage can walk [29]. Brown-Sequard syndrome occurs when the left or right half of the spinal cord is injured.

Its typical cause is traumatic traumas such as gunshot and stabbing wounds, motor vehicle accidents, or fractured vertebrae caused by falls [30].

Other causes of this disorder include spinal disc herniation, cervical spondylosis, tumors, multiple sclerosis, decompression sickness, cystic disease, and infections (such as meningitis, TB, transverse myelitis, and herpes zoster) [31].

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Pathophysiology. Typically, a clean-cut hemisection is invisible in cases with Brown-Sequard syndrome. However, partial hemisection is visible and frequently involves every nerve tract parallel to the damaged region. The following deficiencies might result from a hemisection if the damage was in the cervical region, such as from C5 to T1: The ipsilateral side would lose all sensory perception.

Dorsal Columns Injury. Because dorsal columns ascend ipsilaterally, carrying information from the lower half of the body in the gracile fasciculus and the upper half of the body in the cuneate fasciculus before they decussate in the lower medulla, sensations responsible for fine touch, vibration, two-point discrimination, and conscious proprioception would be affected on the same side of the lesion.

Because the spinothalamic fibers ascend a level and then cross to the opposite side of the cord, they are responsible for pain, temperature, and crude touch; hence, they would be impacted contralateral to the lesion.

Dorsal and Ventral Spinocerebellar Tract Injury. Lesions affecting the dorsal tracts, which are responsible for feelings of unconsciously perceived proprioception, result in ipsilateral dystaxia, while injuries to the ventral tracts cause contralateral dystaxia because these fibers ascend and cross to the other side.

Horner's syndrome. Ipsilateral loss of sympathetic fibers leading to ptosis, miosis, and anhydrosis occurs if the lesion is at or above T1. Also possible is facial redness brought on by vasodilation.

Corticospinal Tract Injury. A lower motor neuron lesion characterized by Loss of muscle mass, fasciculations, diminished power and tone, and an ipsilateral loss of movement at the lesion site would be present. There would be upper motor neuron lesion indications below the lesion level, such as hyperreflexia, paralysis with hypertonia clasp knife type, and positive Babinski sign. The contralateral side does not exhibit any notable motor deficits [33].

ETIOLOGY: There are two categories of injuries that are the most common causes of Brown-Séquard syndrome: traumatic and non-traumatic [34].

Injuries from trauma occur significantly more frequently. Some of the reasons include blunt trauma, car accidents, stabbings, gunshot wounds, and fractured vertebrae from falls [35,36].

Radiation therapy, decompression sickness, tumors, cervical spondylosis, multiple sclerosis, cystic disease, spinal disc herniation, and tumors can all produce Brown-Séquard syndrome to a lesser degree. Other non-vascular causes include ischemia or bleeding. Infectious diseases include meningitis, herpes zoster, TB, and empyema [37,38].

Incomplete Spinal Cord Injury and Associated Syndromes

Central cord syndrome: Normally driven on by a hyperextension injury (such as an automobile accident), central cord syndrome causes paralysis in the upper extremities and retention of urine [39].

Posterior cord syndrome: A posterior spinal cord lesion resulting in hypotonia, reduced deep tendon reflexes, ataxic gait, Loss of proprioception and vibration, and a positive Romberg sign is known as posterior cord syndrome [40].

Anterior cord syndrome: Anterior cord syndrome is brought on by a reduced blood supply to the anterior two-thirds of the spinal cord, which affects the corticospinal and spinothalamic tracts. This results in a loss of temperature, pain at the damaged site, and motor paralysis below it [41].

Brown-Séquard syndrome: Hemisection of the spinal cord resulting in ipsilateral weakness, paralysis, and contralateral Loss of pain is known as Brown-Séquard syndrome. A unilateral lateral cord impairment characterizes it [42].

Conus medullaris syndrome: Conus medullaris syndrome is characterized by abrupt, bilateral back pain, symmetrical and bilateral perianal numbness, fasciculations, urine retention, and impotence. It is caused by compression of the spinal cord at T12-L2 [43].

Cauda equina syndrome: It is brought on by damage to the L2-S4 nerve roots. Cauda equina syndrome is usually unilateral, progressive, and associated with less severe back pain and more severe radicular pain than conus medullaris syndrome. Asymmetric areflexic paraplegia, atrophic paraplegia, and inner thigh numbness (saddle anesthesia) can result from compression of these nerve roots [44].

Complications: A spinal cord injury can result in consequences and disruptions to normal activities. Symptoms may include Loss of bladder or bowel control, muscular tone, muscle spasms, nerve pain, skin sores, lung problems, risk of obesity, and infertility [45] (Figure 5).

Treatment and recovery: Treatment and recovery times vary depending on the type of spinal cord damage sustained. Surgery is the usual treatment for spinal cord injury. Surgery is usually the first option when there is a risk of future injury [46,47.]

Occupational therapy, physical therapy, and rehabilitation are often necessary to improve and maintain long-term quality of life.

The initial symptoms of BSS include the loss of voluntary motor function (muscle movement) on the affected side of the body, below the level of the lesion. This] can manifest as weakness or paralysis. Loss of pain and warmth sensation on the side of the body also are affected by the injury.

DIAGNOSIS:
• Perform a complete physical examination.
• Perform a thorough neurological assessment, including motor and sensory assessment.
• Discuss with a patient his/her medical, neurological, and trauma history.

TEST:
• Magnetic resonance imaging (MRI)

MRI is the most useful imaging test for BSS since it may detect structural abnormalities in spine and assess non-traumatic causes of BSS [49].

Myelogram and computed tomography (CT) of the spine: If a patient cannot have an MRI scan, a myelogram followed by a CT scan might be recommended. These examinations may identify nerve tissue degeneration on one side of the spinal cord. A myelogram is an imaging procedure that evaluates the connection of the vertebrae and disks in spinal column via a spinal cord, nerves, and nerve roots. A CT scan employs X-rays and computers to create detailed images of structures within the body [50].

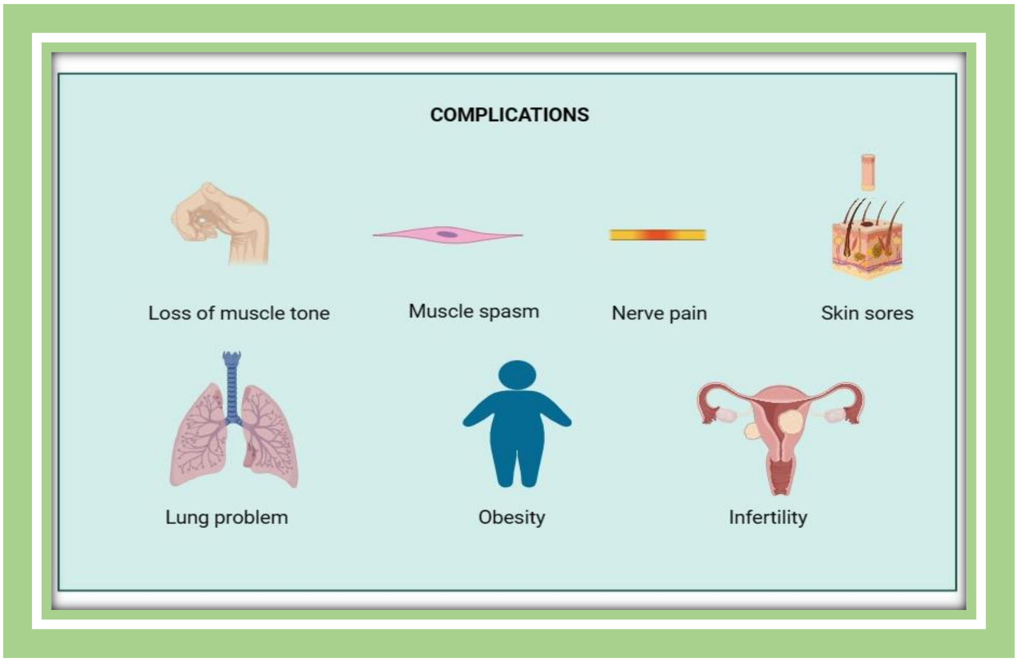

Figure 5. Complications associated with BSS.

Blood tests:
If the reason for the BSS is unknown, the infection cause need to be excluded [51].
• The treatment for Brown-Séquard syndrome (BSS) is based on the underlying cause of spinal cord injury.

The goal of the therapy:
• Improving or maintaining motor and sensory function.
• Preventing secondary injuries and minimizing implications.
General therapy for the first treatment of BSS can include:
SURGERY:
Non-traumatic causes of BSS usually involve mechanical compression or herniation of the spinal cord, requiring surgical intervention to relieve the compression [52].

MEDICAL MANAGEMENT:

- Wound debridement and closure in the case of an open injury.
- Anti-tetanus prophylaxis.
- Antibiotics [53].
- Analgesics.
- Antispasmodics.
- Laxatives [54].

Medications to Prevent Blood Clots: People with spinal cord injuries have the greatest prevalence of venous thromboembolism (VTE) [55,56], including deep vein thrombosis (DVT) and pulmonary embolism, among severe trauma patients. To avoid blood clots, a practitioner should prescribe anticoagulants such as heparin or warfarin.

To Minimize Pressure Injuries: The usual approach is rotating and repositioning a patient body every two hours. Skin needs to be kept clean and dry, followed by hydration [57].

Gastrostomy tube (G-tube) implantation: When spinal cord injuries cause temporary paralysis of the muscular contractions responsible for moving food through the intestines, the condition known as paralytic ileus arises. To lower the danger of abdominal distension brought on by paralytic ileus, and to improve nutrition a G-tube might be needed [58, 59].

Breading support: REATHING SUPPORT: A patient could require a ventilator, a machine that helps breathing difficulties [60].

Neurogenic bladder management: BSS patients, among others, may experience bladder loss of control. More urological treatments and a urinary catheter may be necessary if this occurs [61].

Treatment for autonomic dysreflexia: Individuals with spinal cord injury may have significant variations in blood pressure as well as other symptoms that may require cautious administration of blood pressure and cardiac drugs [62].

Blankets with the temperature Control. People with BSS frequently struggle to control their body temperature. A healthcare staff could offer blankets that regulate temperature to assist with this.

CONCLUSION Brown-Séquard syndrome is a complex medical condition that requires a multi-specialty team to address symptoms, management, and prevention.

Conflicts of interest

All authors declare that there are no conflicts of interest.

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