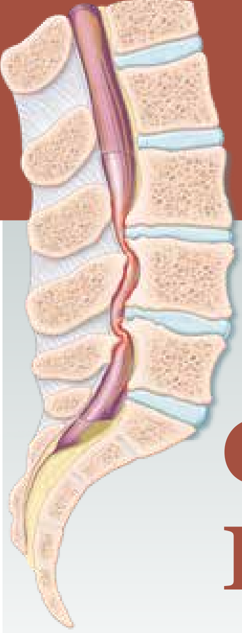

Current Concepts in Spinal Cord Injury: Pearls for Primary Care Management

ABSTRACT

Traumatic spinal cord injury (tSCI) is a devastating condition that can lead to severe and permanent sensory, motor, and autonomic dysfunction, significantly impacting an individual's ability to function independently. Recent demographic changes have resulted in a notable increase in tSCI among the elderly, with falls emerging as the primary cause. Early recognition and prehospital management are crucial, emphasizing restriction of spinal motion and timely transfer to specialized centres. Since the time from injury to surgery significantly affects outcomes, decompression should not be delayed and offered in a timely manner to all tSCI patients. Additionally, emergent trauma care including conducting a thorough neurological assessment, maintaining adequate blood pressure and adopting a multidisciplinary approach, is essential for optimizing neurological outcomes and addressing long-term complications.

KEYWORDS: Early surgery, geriatric trauma, neurotrauma, traumatic spinal cord injury

CME Pre-test Quiz

Introduction

Neurotrauma involving the brain and spine is considered a silent epidemic in modern times.[1] Spinal cord injury (SCI) is a significant public health concern, with traumatic causes contributing to up to 90% of cases. Traumatic SCI (tSCI) predominantly affects the male population and has far-reaching implications for both individuals and society. The devastating consequences of tSCI, including profound motor, sen-

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sory, and autonomic impairments, underscore the urgent need for effective prevention and management strategies. In recent years, demographic shifts, driven by advancements in healthcare and increased life expectancy, have led to a burgeoning elderly population worldwide.[2] As a result, the epidemiology of tSCI is undergoing significant transformation, with a notable increase in incidence and prevalence among older adults. This article explores the evolving landscape of tSCI epidemiology and management strategies, with a focus on the growing incidence among the elderly population and its impact for primary care physicians.

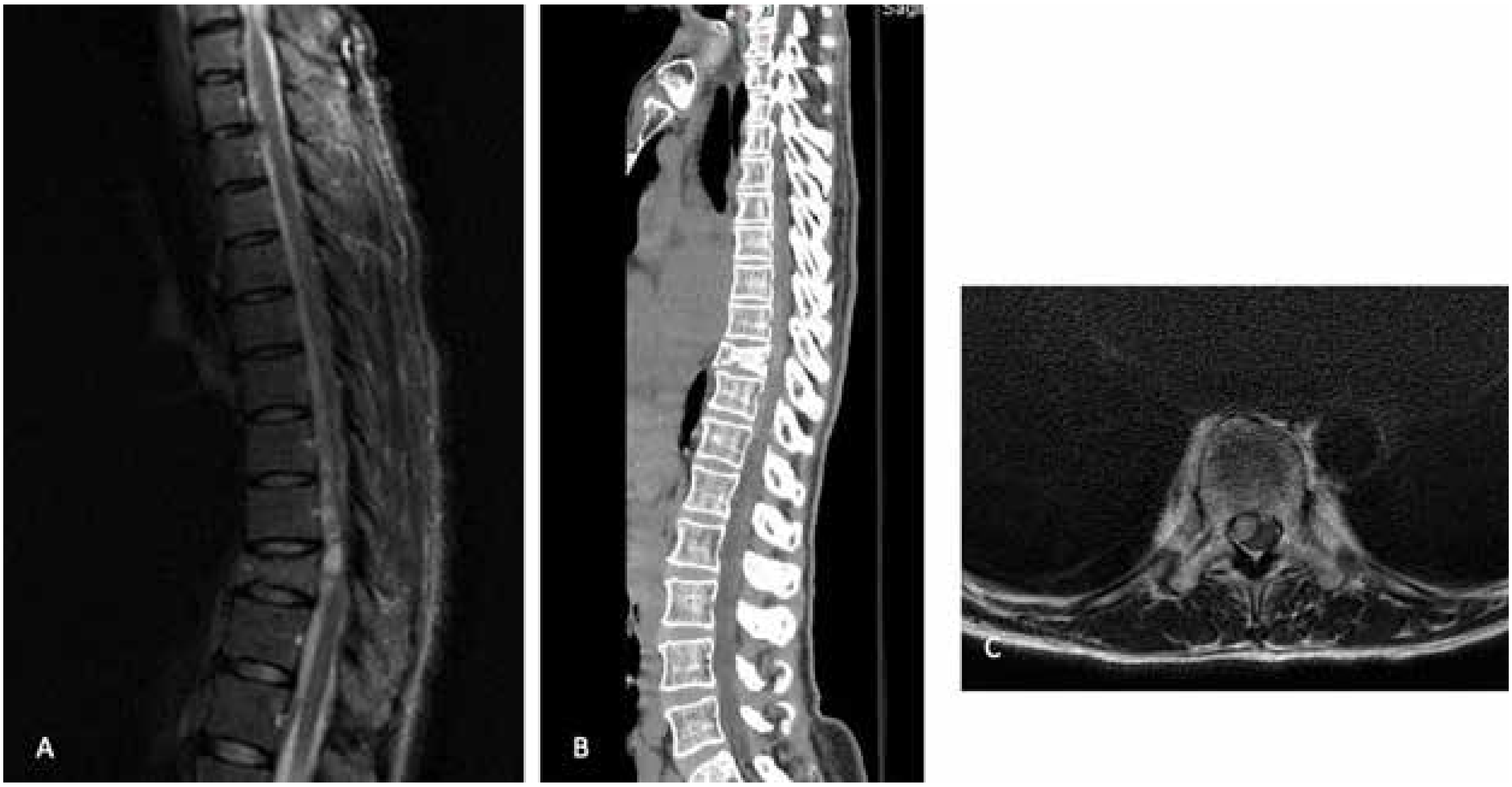
The Shifting Epidemiology of Spinal Cord Injury

Globally, the incidence of SCI was estimated to be 0.9 per million in 2019, with a notable temporal trend showing an increase in incidence and prevalence with age over the past three decades.[3] It is projected that by 2032, patients over 70 years old will represent the majority of tSCI in Canada.[4] Historically, traumatic injuries resulting from motor vehicle accidents (MVCs) were the primary cause of SCI. However, recent studies demonstrate a shift in the etiology of tSCI, with falls becoming the leading cause, especially among the elderly population.[5] Analysis of longitudinal data reveals a significant increase in the mean age of SCI patients over the years, accompanied by a rise in fall-related injuries.[6] As the size of the elderly population continues to grow, there is a crucial need for heightened awareness and proactive measures to address the rising incidence of tSCI among this vulnerable portion of our population.

CASE STUDIES

Case 1: Thoracic Burst Fracture

A 68-year-old female presents in the emergency room after slipping and falling on the bathroom floor. She complains of severe low back pain and is unable to walk after the fall. Physical examination reveals the last normal sensory level to be at the T12 dermatome and weak bilateral lower extremities (MRC 2/5 on the left leg and 3/5 on the right leg on manual muscle testing). Deep tendon reflex examination is hyporeflexic on knee jerk testing bilaterally, and she has weak sphincteric tone but intact perianal sensation. Initial assessment in the ER follows ATLS protocol with comprehensive evaluation of airway, breathing, and circulation alongside spinal precaution using the log-roll technique. Urgent MRI and CT reveal a burst fracture of T10 with associated epidural hematoma. She is started on high dose

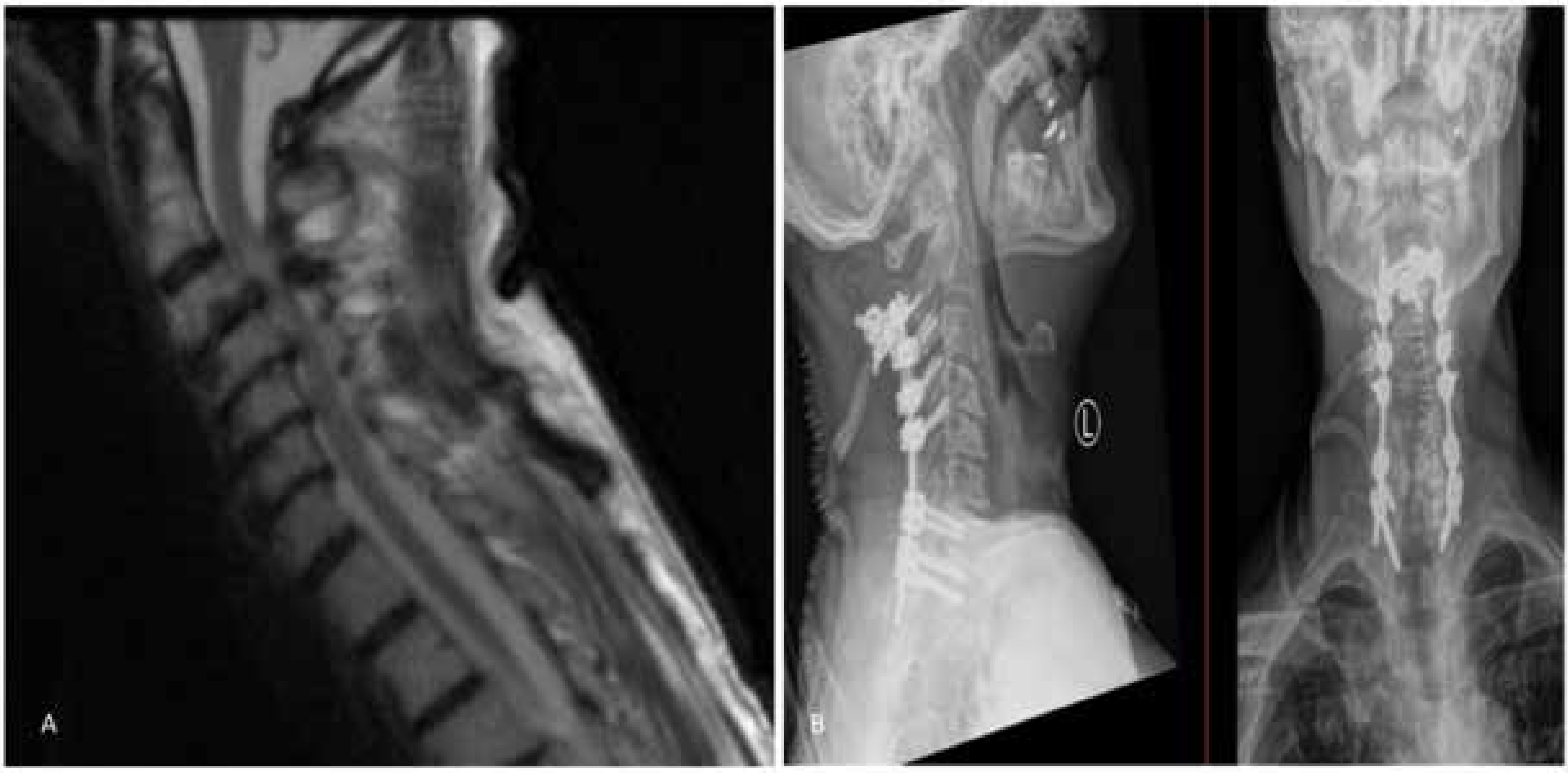


A. MRI sagittal T2 image revealing ventral epidural hematoma and burst fracture of T10. **(B)** CT scan showing bilateral endplate fracture with loss of vertebral body height. **(C)** Cross sectional MRI image showing severe cord compression from hematoma occupying the spinal canal

methylprednisolone and taken to the OR urgently for decompression, evacuation of hematoma, and fusion spanning the T9-T11 level. Postoperatively she is monitored in the post anesthesia care unit (PACU) with emphasis on maintaining MAP at 85 mmHg avoiding any episodes of hypoxia and hypotension. Early postoperative rehabilitation focuses on gait training, range of motion exercises and activities of daily living. Additionally, measures to prevent complications such as pressure ulcers and deep venous thrombosis are implemented.

Case 2: Central Cord Syndrome

A 65-year-old male presents to the emergency department following a fall where he struck his head on a metal post. He had a rapid decline in hand function following the fall and was unable to stand to ambulate. Additionally, he complained of severe burning sensation in both hands. On physical examination, he had a Glasgow coma scale (GCS) of 15 and had a large bleeding laceration on his forehead. Manual motor testing revealed 3/5 strength in deltoid and biceps, and 2/5 strength in his triceps and hand grip bilaterally. He has 4/5 strength on all muscle groups of both lower extremities. Additionally, he demonstrated allodynia to light touch on both hands and a positive Hoffman's sign. The sensory exam was otherwise normal. Clinical features were highly suggestive of ASIA C, acute



A. T2WI MRI showing multilevel spinal cord compression from degenerative disc disease; **(B)** Early Posterior cervical compression and fusion

traumatic central cord syndrome (ATCCS) with ongoing compression. Immediate C-spine precaution commenced to prevent further SCI, with vigilant monitoring for vital signs to avoid hypoxia, hypotension, and bradycardia. Diagnostic imaging including cervical CT and magnetic resonance imaging promptly assessed the extent of SCI and identified any associated compression or ligamentous injuries. Given the clinical diagnosis of ATCCS with ongoing compression, he was brought to the OR for decompressive laminectomy with fusion within 24 hours of admission. Surgery was intended to alleviate pressure on the spinal cord and optimize neurological outcomes. Intraoperative monitoring of blood pressure (avoiding SBP <90 mmHg) and mean arterial pressure (MAP 80) meticulously maintained adequate spinal cord perfusion and mitigated the risk of ischemic injury. Following surgery, he was transferred to the intensive care unit for close monitoring of neurological and cardiopulmonary status. Early postoperative rehabilitation was initiated including physical therapy and occupational therapy to promote recovery and prevent complications such as muscle atrophy and joint contractures. Multidisciplinary collaboration involving the neurosurgeon, rehabilitation specialist, and nursing staff was integral to the patient's postoperative care rehabilitation process. Throughout hospitalization and rehabilitation, pain was adequately managed, and his nutritional status was optimized to support his overall recovery.

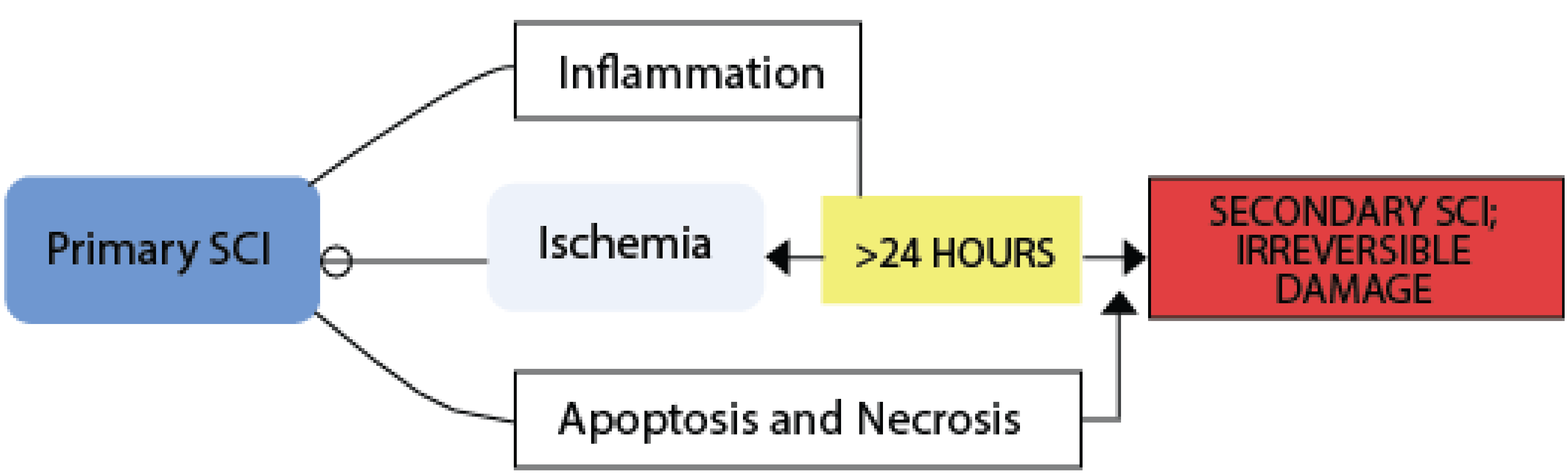
Prehospital Management of Spinal Cord Injury Patients

Acute tSCI involves two distinct phases: primary and secondary. (Figure 1) The initial impact, typically in the form of fractures or dislocations, induces axonal injury, cellular membrane destruction and microhemorrhages in the white and gray matter. A cascade of secondary events follows the primary injury, including edema, release of coagulation factors, ionic imbalance, and the formation of free radicals, resulting in impaired neuronal homeostasis, apoptosis, and tissue destruction.[7]

In approximately 25% of SCIs symptoms appear after the initial trauma, with at least 5% of patients experiencing new or worsening symptoms upon arrival at the emergency room. Nearly one-third of individuals with tSCI are diagnosed with unstable fractures and SCI-specific care must address the injury site.[8,9,10] Spinal instability arises when fractures and/or dislocations render the spinal column unable to maintain its normal protective configuration, predisposing individuals to further injuries.[11]

The cervical spine is the site of tSCI in 55% of cases with the thoracic spine, the thoracolumbar junction and the lumbosacral region each accounting for 15%. Approximately 10% of patients diagnosed with fractures in one segment of the spine exhibit a second, noncontiguous fracture. Excessive manipulation or inappropriate restriction of spinal motion can exacerbate secondary damage and adversely affect patient outcomes.[9]

Figure 1: Pathophysiology of Traumatic Spinal Cord Injury



Following the primary injury, a secondary cascade characterized by vascular disruption, ischemia, inflammation, and oxidative stress culminate in irreversible cell death, axonal injury, and formation of the glial scar. This time-dependent downstream process highlights the importance of early intervention in patients with tSCI.

Spinal Immobilization and Patient Transport

Along with airway protection and blood pressure management, spinal immobilization and patient transport are critical components of initial trauma care, particularly for individuals with suspected spinal injuries. Timely transfer to a specialized SCI treatment center is imperative to facilitate early intervention and enhance neurological outcomes.[8,12]

Spinal immobilization protocols, necessitating placement on a rigid long backboard coupled with a rigid cervical collar, apply to both conscious and unconscious patients. Additional measures, such as securing the head with tape or blocks and restraining the arms alongside the body using straps, ensures safe transportation to medical facilities.[13] Despite appropriate application, spinal immobilization carries inherent risks, including pain, delayed transport, pressure ulcers, and potential aspiration so the use of backboards should be limited with prompt removal as soon as possible.

For unconscious trauma victims, maintaining cervical collar placement is imperative until imaging tests to ascertain the presence or absence of spinal injury. Various protocols, including those outlined by the Advanced Trauma Life Support (ATLS), the European Trauma Course (ETC), the National Emergency X-Radiography Utilization Study (NEXUS), and the Canadian Cervical Spine (C-spine) rule, offer guidance on the safe removal of cervical collars in conscious patients.[10] Currently, individuals meeting specific criteria such as: (1) no spinal pain or tenderness, (2) no significant multiple system trauma, (3) no significant head or facial trauma, (4) no extremity neurological deficit, (5) no loss of consciousness, (6) no altered mental status, (7) no known or suspected intoxication, and (8) no significant distracting injury, are deemed suitable candidates for cervical collar removal.[8]

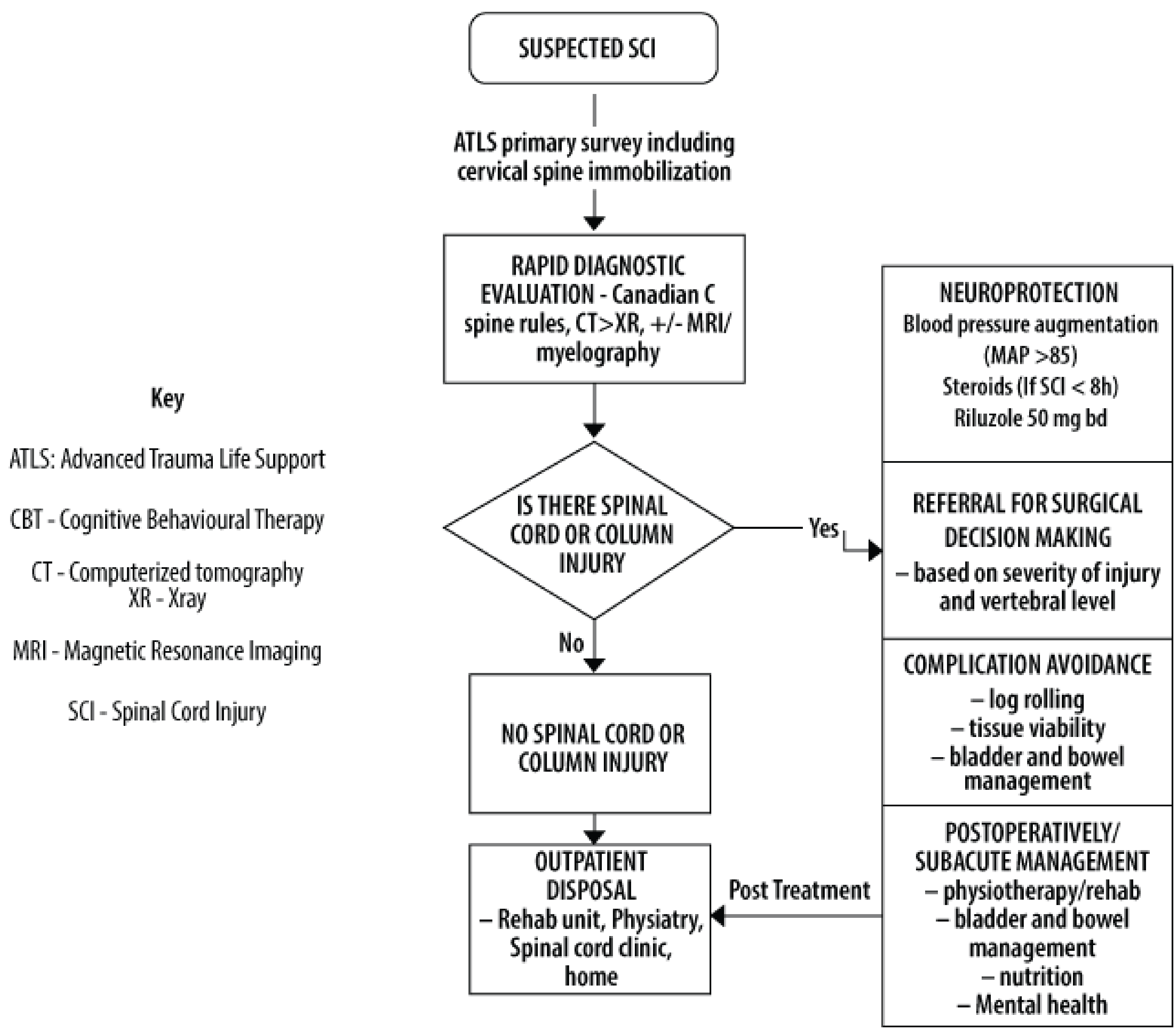
Emergent Trauma Care

Patient evaluation in the trauma bay should adhere to the ATLS protocol, conducted by team members proficient in its procedures. (Figure 2) Since up to 80% of polytraumatized patients may have tSCI, airway assessment should be conducted with the presumption of spinal column injury.[13] Until the radiological exclusion of ankylosing conditions like ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis (DISH), it is advisable to stabilize the cervical spine with blocks, since the forced application of a rigid collar can displace a spinal fracture producing spinal cord compression.

During the disability assessment of the primary survey, evaluating consciousness level using tools like the Glasgow coma scale

(GCS) and gross limb movement relative to gravity is essential. This information aids not only in prognostication but also in determining the patient's suitability for provocative maneuvers such as skull traction in the case of cervical spine fracture subluxation injuries. The presence of point tenderness on spine palpation or step deformities may be an early indication of an unstable spinal column. Based on the International Standards for Neurological Classification and Spinal Cord Injury (ISNCSCI) protocol, the complete assessment of tSCI patients involves examination of both motor and sensory function of upper and lower extremities as well as assessment of deep anal

Figure 2: **Suggested Management Workflow for the Neurocritical Care of tSCI Patients**



pressure (DAP) and voluntary anal contraction (VAC)

Systemically assessing life-threatening injuries and optimizing cardiopulmonary function is the foremost priority. The most recent guideline by the AO Spine/Praxis Institute advocates for augmentation of the mean arterial pressure (MAP) to at least 75-80 mmHg but not higher than 90-95mmHg for a duration of 3-7 days in order to optimize spinal cord perfusion.[14] Blood pressure augmentation to reach these targets, however, must be highly individualized and precautions must be observed in patients suspected of having massive hemorrhages within the cranium, viscera, or vascular beds.

Imaging in Traumatic Spinal Cord Injury

The current standard for acute imaging in trauma is Maximum Intensity Protocol Computed Tomography (MIP-CT). This typically includes non-contrast head and cervical spine scans, as well as CT scans of the chest, abdomen and pelvis with and without intravenous contrast, which can generate reconstructed images of the thoraco-lumbo-sacral spine. Plain radiographs, while useful for extremity imaging, are associated with a high rate of false negatives when used for spinal imaging and are not recommended. Angiography may be necessary in cases involving craniovertebral junction injuries, unstable maxillofacial injuries, cervical fracture dislocation such as jumped facets, and fractures through the transverse foreman. CT scans provide superior depiction of bony spinal canal anatomy in trauma patients but are unable to screen for ligamentous injury and spinal cord lesions.

Magnetic Resonance Imaging (MRI) can evaluate disco-ligamentous injuries, spinal cord edema, or hematomyelia, particularly in cases where the significant clinical findings are not consistent with benign-appearing CT imaging, such as with occult ankylosed cervical spine fractures. MRI can detect spinal cord edema or occult ligamentous injury, which may not be evident on CT scans alone. MRI criteria are incorporated into trauma decision-making tools like the Thoracolumbar Injury Classification Schema (TLICS). However, MRI also presents challenges, including long acquisition times, limited availability of machines causing delays in accessibility for patients in critical condition and contraindication in patients with retained metals.

Bozo *et al.* recommended the use of MRI in SCI management and prognostication based on moderate evidence, suggesting that all spinal MRI should include a sagittal T2 sequence to identify mechanical SCI, transection, compression, or edema.[15] The inherent delays in obtaining MRI imaging must be balanced against the urgency of implementing definitive care.

Neurocritical Care of the Injured Spinal Cord

Neurogenic shock leading to autonomic instability is a critical complication of SCI, particularly with cord trauma at or above T6. In its early stages, neurogenic shock manifests as refractory hypotension and life-threatening bradycardia, necessitating inotropic (the strength of the cardiac contraction) and chronotropic (cardiac rate and rhythm) support. Subacute manifestations, associated with blocked hollow viscera, may include labile blood pressure and pulse rates. This is termed autonomic dysreflexia and requires medical intervention.

Recommendations for managing neurogenic shock include treatment to avoid hypotension (defined as systolic BP <90 mmHg) with vasopressor administration as needed. Dopamine, which supports both chronotropic and inotropic cardiac function, is a preferred pressor, while combined alpha and beta-adrenergic agents like norepinephrine are considered second-line options. Atropine is the preferred treatment for isolated bradycardia; vasoactive agents may induce reflex bradycardia.

Respiratory depression is a significant concern in SCI patients, particularly those with diaphragmatic paralysis from higher cervical spine lesions (C3-5) or denervation of thoracic accessory muscles due to thoracic root injuries. Decreased or absent cough and gag reflexes increase the risk of aspiration pneumonia and atelectasis.

Early intensive care is recommended to evaluate the need for intubation in patients with high cervical spine injuries. Patients with SCI causing respiratory impairment should receive pneumococcal and influenza vaccinations and physiotherapy with percussion maneuvers. Pulmonary toileting is crucial.

Maintaining target MAP (at least 75-80 mmHg but not higher than 90-95mmHg) for 3-7 days is recommended to improve spinal cord recovery outcomes. Riluzole, a sodium channel blocker, has demonstrated the ability to mitigate the secondary injury cascade in animal models of tSCI.[16] Despite the premature termination of the RISCIS Study (Safety and Efficacy of Riluzole in Acute Spinal Cord Injury Study) leading to underpowered results, pre-planned secondary analysis suggested the drug had potential efficacy and might be a therapeutic option for tSCI patients within 12 hrs of injury.[17] The use of steroids in SCI management has been extensively studied and has shown mixed results. Although high dose methylprednisolone administered within 8 hours postinjury for 24 hours has shown improved motor score recovery, the controversy surrounding its use persists, with recommendations varying among different medical organizations.[18] Therefore, the decision to administer steroids should be made on a case-by-case basis, considering the individual patient's condition and preferences. (Table 1)

"Time is the Spine": The Importance of Early Surgical Intervention in tSCI

The primary goals of surgical intervention in spinal trauma are to relieve ongoing neural compression, stabilize the damaged spinal column, and restore natural alignment. Surgical decision-making involves a comprehensive assessment of clinical and radiographic parameters, aided by tools such as the Subaxial Injury Classification Score (SLICS), Thoracolumbar Injury Classifications Score (TLICS), and the AO Spine Trauma group's alpha numeric rating system. These tools categorize the type and severity of the injury and provide management recommendations for each category.

The primary traumatic cord injury is irreversible which emphasizes the importance of timely intervention to halt the evolution of the highly deleterious secondary injury cascade. The Surgical Timing in Acute Spinal Cord Injury Study (STASCIS) trial provided the first comprehensive evidence that surgery within the first 24 hours leads to at least a two grade improvement in the ASIA Impairment Score (AIS) compared later surgery.[19] This study introduced the now widely acknowledged principle of "Time is Spine." A more recent meta analysis supported the concept, showing that decompressive surgery within 24 hrs leads to improvement in the ASIA motor score and better AIS grades, signifying less severe impairment, compared to results from surgery more than 24 hours after injury.[19] Ongoing research is exploring the risk-benefit ratio of early versus ultra-early decompressive surgery to further refine timing recommendations.

Subacute and Long-Term Complications of tSCI

Subacute to long-term management of tSCI patients begins during the index admission and requires anticipation and proactive management of various complications. Tissue viability management is crucial to prevent decubitus ulcers, which can lead to sepsis and high mortality rates. Limb-oriented physical therapy during inpatient rehabilitation helps prevent fixed flexion deformities and facilitates adaptation to new functional abilities.

Traumatic SCI ranks as one of the costliest chronic conditions. Estimates from the Canadian Research Institute estimate the lifetime economic burden of tSCI to be 1.5M CAD for incomplete tetraplegia and 3.0M CAD for complete tetraplegia.[20] The reintegration of elderly tSCI patients into the com-

Table 1: Summary of Recommendations for tSCI Management

Immediate Management	ATLS principle for assessment and identification of extent of injury
	Detailed neurological examination in accordance with ISNCSCI
	Close monitoring for cardiorespiratory compromise – Maintain SBP > 90 mmHg and MAP at least 75-80 but not higher than 90-95 mmHg x 3-7 days
	Spine motion restriction
	Immediate transfer to SCI-specialized centers
Acute Management	Consider administering MPSS for 24 hrs according to the NASCIS II* protocol (if within 8 hrs) – MPSS use is an option as per the 2017 AO Spine guidelines and its use should be discussed with the specialist team
	Early decompression (within 24 hrs)
	Prompt imaging (CT and MRI) to identify extent of primary and associated spinal injury
	Riluzole is an emerging option which has shown promising results in a Phase III RCT, but which has not yet been endorsed by clinical practice guideline groups.
Subacute and long-term management	Gastric Ulcer Prophylaxis
	Thromboembolic prophylaxis (within 72 hrs if without contraindication)
	Early nutritional support
	Early rehabilitation
	Consideration for mental health, social and spiritual support

*MPSS 30 mg/kg bolus at admission followed by 5.4 mg/kg//hr for 23 hrs
AO - Arbeitsgemeinschaft für Osteosynthesefragen (Association of the Study of Internal fixation), ATLS – advance trauma life support, CT – computed tomography, ISNCSCI – International Standards for Neurological Classification of Spinal Cord Injury, MAP – mean arterial pressure, MRI – magnetic resonance imaging, NASCIS – National Acute Spinal Cord Injury Study, SBP – systolic blood pressure, SCI – spinal cord injury

SUMMARY OF KEY POINTS

Falls are increasingly becoming the primary cause of traumatic spinal cord injury, particularly among the elderly population, underscoring the need for heightened awareness and proactive preventive measures.

Early recognition and appropriate prehospital management, including prompt transfer to specialized trauma centers, are crucial in saving the injured spine.

Neuroprotective strategies, such as maintaining adequate spinal cord perfusion and implementing early surgical decompression, are essential for attenuating the secondary injury cascade.

Multidisciplinary care is imperative for restoring functional independence, with a comprehensive approach addressing not only physical rehabilitation but also social, mental, and spiritual needs in patients with tSCI.

munity and the restoration of their independence hinge upon adequate training in adapting to new needs and the community's commitment in the provision of adequate facilities and rehabilitation programs. A multidisciplinary approach involving professionals from occupational therapy, physical therapy, speech therapy and neuropsychology is imperative both during acute care and at time of discharge. In geriatric tSCI, spirituality and social support play integral roles in

CLINICAL PEARLS

With an aging population and more fall-related mechanisms, the most common form of spinal cord injury (SCI) is an incomplete cervical SCI called central cord injury where the arms and hands are more affected than the legs. These patients usually have pre-existing degenerative changes and can experience cord contusion in the absence of a cervical fracture.

"Time is spine" is a key principle which guides spinal cord injury management. Most patients with a SCI require surgery, optimally within 24 hours after injury. Expeditious workup and referral/transfer of patients with a SCI to a specialized spine facility is important.

Be aware that 10-15% of patients with one spine fracture will have a second non-contiguous spine fracture. The presence of a spine fracture in one area should prompt a full spine CT.

Hemodynamic management of patients with a spinal cord injury is important to maintain cord perfusion. Mean arterial pressure should be maintained at greater than 80 mm Hg.

Methylprednisolone (a potent ant-inflammatory corticosteroid) and riluzole (a sodium-glutamate antagonist) are options in treating patients with an acute spinal cord injury and are optimally given within 8-12 hours after injury.

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fostering resilience and enhancing well-being.

Effective management of bladder and bowel function, including careful catheterization strategies, is essential to mitigate the risk of autonomic dysreflexia triggered by hollow viscus obstruction. Paralyzed bowel increases susceptibility to cecal perforation and intraabdominal sepsis, while an atonic bladder elevates the risk of urogenital infections and stone formation.

Nutritional planning is vital, especially for quadriplegic patients who may require tube feeding, predisposing them to malnutrition and electrolyte disturbances. The inclusion of a nutritionist in the multidisciplinary team is pivotal to ensure comprehensive care.

Given the heightened risk of depression and suicidal ideations among tSCI patients due to the life-changing nature of their condition, mental health support is critical but often overlooked.[21] Early involvement of the mental health team, including consideration of cognitive behavioral therapy and pharmacological interventions, is needed to address these psychological challenges. (Table 1)

Conclusion

Driven by demographic shifts and advances in healthcare, the landscape of tSCI management is rapidly evolving. Supported by robust evidence demonstrating improved neurological outcomes with timely decompression, the recognition of "Time is Spine" underscores the critical importance of early surgical intervention. The increasing incidence of tSCI among the elderly population necessitates a comprehensive approach to subacute and long-term management, addressing not only physical complications but the psychosocial and economic aspects. Multidisciplinary collaboration, proactive tissue viability management, and tailored rehabilitation strategies will optimise outcomes and restore independence. Continued research and innovation are essential to further refine management strategies and improve the quality of life for individuals affected by tSCI.

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