Diagnosis and management of traumatic cervical central spinal cord injury: A review

Nancy E. Epstein, Renee Hollingsworth

Department of Neuroscience, Winthrop University Hospital, Mineola, NY 11501, USA

E-mail: *Nancy E. Epstein - nancy.epsteinmd@gmail.com; Renee. Hollingsworth - rhollingsworth@winthrop.org

*Corresponding author

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Abstract

**Background:** The classical clinical presentation, neuroradiographic features, and conservative vs. surgical management of traumatic cervical central spinal cord (CSS) injury remain controversial.

**Methods:** CSS injuries, occurring in approximately 9.2% of all cord injuries, are usually attributed to significant hyperextension trauma combined with congenital/acquired cervical stenosis/spondylosis. Patients typically present with greater motor deficits in the upper vs. lower extremities accompanied by patchy sensory loss. T2-weighted magnetic resonance (MR) scans usually show hyperintense T2 intramedullary signals reflecting acute edema along with ligamentous injury, while noncontrast computed tomography (CT) studies typically show no attendant bony pathology (e.g. no fracture, dislocation).

**Results:** CSS constitute only a small percentage of all traumatic spinal cord injuries. Aarabi *et al.* found CSS patients averaged 58.3 years of age, 83% were male and 52.4% involved accidents/falls in patients with narrowed spinal canals (average 5.6 mm); their average American Spinal Injury Association (ASIA) motor score was 63.8, and most pathology was at the C3-C4 and C4-C5 levels (71%). Surgery was performed within 24 h (9 patients), 24–48 h (10 patients), or after 48 h (23 patients). In the Brodell *et al.* study of 16,134 patients with CSS, 39.7% had surgery. In the Gu *et al.* series, those with CSS and stenosis/ossification of the posterior longitudinal ligament (OPLL) exhibited better outcomes following laminoplasty.

**Conclusions:** Recognizing the unique features of CSS is critical, as the clinical, neuroradiological, and management strategies (e.g. conservative vs. surgical management; early vs. late) differ from those utilized for other spinal cord trauma. Increased T2-weighted MR images best document CSS, while CT studies confirm the absence of fracture/dislocation.

**Key Words:** Cervical, central cord injury, conservative therapy, spinal trauma, surgery
INTRODUCTION

Traumatic cervical central cord spinal injuries (CSS) are now more readily recognized both clinically and on magnetic resonance (MR) scans. McKinley found that 9.2% of all spinal cord injuries were attributed to central spinal cord syndromes (CSSs; 77 of 839). When presenting to emergency rooms, typically with greater upper vs. lower extremity neurological deficits, CSS patients first undergo computed tomography (CT) studies to rule out fracture/dislocation, and secondarily have MR examinations looking for classical central cord contusion/edema/hematomas, along with other factors (e.g., ligamentous injury, disc herniations) [Table 1]. The management of these injuries with or without surgery remains controversial [Table 1]. When surgery is chosen, there is continued debate regarding the optimal surgical approach (e.g., anterior, posterior, circumferential), and whether it should be performed early vs. late (e.g., the latter allows the patient’s neurological status to plateau). Here we review the various clinical presentations, neuro-diagnostic findings, and therapeutic (nonsurgical vs. surgical) strategies for diagnosing and managing CSS [Tables 1 and 2].

Table 1: Protocol for CSS diagnosis/management

DEFINITION OF CENTRAL CORD SYNDROME

Central cord syndrome

Nowak et al. considered CSS to be the most common type of incomplete spinal cord injury that typically occurs following traumatic hyperextension events in older patients with underlying cervical spondylosis/stenosis [Table 2]. Neurological deficits typically involve the upper extremities more than the lower extremities, and are characterized by greater motor as compared with spotty/inconsistent sensory impairment. Deficits may vary from weakness in the hands/forearms with relative sensory preservation, to severe quadriaparesis (with sacral sparing consistent with an incomplete injury). The optimal treatment remains controversial (nonsurgical vs. surgical performed early vs. late). Furthermore, if surgery is performed, as indicated based on preoperative MR findings of severe compression/stenosis, patients rarely fully recover.

Epidemiology of severe cervical spinal trauma in the north area of São Paulo city

Santos et al. evaluated cervical spinal trauma (CST) data over a 10-year period, 1997–2006 [Table 2]. The 217 patients with CST (21.6 cases annually/1.8 cases monthly) averaged 36.75 years of age. 88% were male, and 174 (80.2%) had cervical subaxial lesions. Of the 2 patients presenting with initial American Spinal Injury Association (ASIA) Grade E scores that evolved to Grade D, one developed a central cord syndrome (CCS).

INJURY MECHANISMS AND DAMAGE AFTER ACUTE CENTRAL CORD SYNDROMES: ANIMAL MODEL

Acute central cord syndrome: Injury mechanisms

Li and Dai assessed the stress distribution to the cervical cord under different injury conditions to better understand the etiology of acute CSSs [Table 2]. Histopathologic studies typically revealed that CSS occurs due to predominant white matter injury. In their feline model, cervical cord injuries were simulated in hyperextension (pinch force anterior (A) or posterior (B); flexion injuries (C)), and vertical compression (pinch force anterior (D) or posterior (E)). Results were analyzed utilizing a representative cross-section analysis. They attributed upper extremity weakness to damage involving the corticospinal tracts and motor neurons in the anterior horn. Hyperpathia was due to damage to the anterior funiculus, posterior horn, and fasciculus cuneatus.
Table 2: Summary of sections

| Title of Section                                               | Summaries                                                                                                                                                                                                 |
|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| **INTRODUCTION**                                              | Summary: The management of these injuries with or without surgery remains controversial [Table 1]. Here we review the various clinical presentations, neuro-diagnostic findings, and therapeutic (nonsurgical vs. surgical) strategies for diagnosing and managing CSS [Tables 1 and 2] |
| **DEFINITION OF CENTRAL CORD SYNDROME**                       | Summary: Nowak et al. noted that central cord syndromes (CCSs) are the most common form of incomplete spinal cord injuries that typically occur following hyperextension trauma in older patients with underlying cervical spondylosis/stenosis.[25] Neurological deficits typically involve the upper more so than the lower extremities, and are accompanied by greater motor than sensory impairment (the latter often spotty). The optimal treatment remains controversial (e.g., nonsurgical vs. surgical (early vs. late for those with MR findings of severe compression/stenosis) |
| Central Cord Syndrome                                         | Summary: When Santos et al. evaluated 217 patients with cervical spinal trauma (CST) data over a 10-year period 1997-2006, 174 (80.2%) had cervical subaxial lesions, and 1 of 2 patients presenting with initial ASIA Grade E improving to Grade D had a CCS.[10] |
| **Epidemiology of Severe Cervical Spinal Trauma in the North Area of São Paulo City** | Summary: Li and Dai’s assessed the stress distribution to the cervical cord under different injury conditions to better understand the etiology of acute CCSs.[20] In a feline model, cervical cord injuries were simulated utilizing five traumatic conditions. They attributed upper extremity weakness to damage to the corticospinal tracts and motor neurons in the anterior horn, while hyperpathia was due to damage localized to the posterior horn, anterior funiculus, and fasciculus cuneatus |
| **INJURY MECHANISMS AND DAMAGE AFTER ACUTE CENTRAL CORD SYNDROMES: ANIMAL MODEL** | Summary: Evaluation of traumatic central cord syndromes (TCCS) characterized by incomplete spinal cord injuries utilizing Medline to review articles regarding central cord injury (CSS). They are the most frequent cause of incomplete traumatic cord injuries. Schneider et al. originally described a series of 15 patients with CSS injuries without fracture dislocation, noting the etiology to be acute disc herniations in the young population, and hyperextension injuries with stenosis in the older group. The pathoanatomic etiologies of these injuries are variously attributed to hematomyelia, vascular insult/ischemia (vertebral artery compression), or mechanical injury. On T2-weighted MR studies, hyperintense signals in the cord typically involves the lateral funiculus, and fasciculus cuneatus |
| **Acute Central Cord Syndrome: Injury Mechanisms**             | Summary: Epstein et al., in 1980, published one of the first articles observing the incidence of traumatic myelopathy occurring in patients with cervical spinal stenosis without fracture or dislocation.[10] Their study looked at the subset of patients from a spinal cord injury study in which no specific lesion could be identified utilizing X-ray and CT studies (MR not yet available) to define the etiology of patient’s CSS |
| **ETIOLOGY OF CENTRAL CORD INJURIES**                         | Summary: Harrop et al. evaluated the pathophysiology, management, and outcomes of acute traumatic central cord syndromes/injuries utilizing Medline to review articles regarding central cord injury (CSS).[15] They are the most frequent cause of incomplete traumatic cord injuries. Schneider et al. originally described a series of 15 patients with CSS injuries without fracture dislocation, noting the etiology to be acute disc herniations in the young population, and hyperextension injuries with stenosis in the older group. The pathoanatomic etiologies of these injuries are variously attributed to hematomyelia, vascular insult/ischemia (vertebral artery compression), or mechanical injury. On T2-weighted MR studies, hyperintense signals in the cord typically involves the lateral white matter tracts (corticospinal); autopsy specimens further demonstrated axonal and myelin loss in these tracts |
| **CSS: Traumatic Myelopathy in Patients with Stenosis**        | Summary: Harrop et al. evaluated the pathophysiology, management, and outcomes of acute traumatic central cord syndromes/injuries utilizing Medline to review articles regarding central cord injury (CSS). They are the most frequent cause of incomplete traumatic cord injuries. Schneider et al. originally described a series of 15 patients with CSS injuries without fracture dislocation, noting the etiology to be acute disc herniations in the young population, and hyperextension injuries with stenosis in the older group. The pathoanatomic etiologies of these injuries are variously attributed to hematomyelia, vascular insult/ischemia (vertebral artery compression), or mechanical injury. On T2-weighted MR studies, hyperintense signals in the cord typically involves the lateral white matter tracts (corticospinal); autopsy specimens further demonstrated axonal and myelin loss in these tracts |
| **Without Fracture/Dislocation**                              | Summary: Harrop et al. evaluated the pathophysiology, management, and outcomes of acute traumatic central cord syndromes/injuries utilizing Medline to review articles regarding central cord injury (CSS). They are the most frequent cause of incomplete traumatic cord injuries. Schneider et al. originally described a series of 15 patients with CSS injuries without fracture dislocation, noting the etiology to be acute disc herniations in the young population, and hyperextension injuries with stenosis in the older group. The pathoanatomic etiologies of these injuries are variously attributed to hematomyelia, vascular insult/ischemia (vertebral artery compression), or mechanical injury. On T2-weighted MR studies, hyperintense signals in the cord typically involves the lateral white matter tracts (corticospinal); autopsy specimens further demonstrated axonal and myelin loss in these tracts |
| **Central Cord Injury: Pathophysiology, Management, and Outcomes** | Summary: Harrop et al. evaluated the pathophysiology, management, and outcomes of acute traumatic central cord syndromes/injuries utilizing Medline to review articles regarding central cord injury (CSS). They are the most frequent cause of incomplete traumatic cord injuries. Schneider et al. originally described a series of 15 patients with CSS injuries without fracture dislocation, noting the etiology to be acute disc herniations in the young population, and hyperextension injuries with stenosis in the older group. The pathoanatomic etiologies of these injuries are variously attributed to hematomyelia, vascular insult/ischemia (vertebral artery compression), or mechanical injury. On T2-weighted MR studies, hyperintense signals in the cord typically involves the lateral white matter tracts (corticospinal); autopsy specimens further demonstrated axonal and myelin loss in these tracts |
| **Acute Traumatic CSS; Clinical and Radiological Correlations** | Summary: Harrop et al. evaluated the pathophysiology, management, and outcomes of acute traumatic central cord syndromes/injuries utilizing Medline to review articles regarding central cord injury (CSS). They are the most frequent cause of incomplete traumatic cord injuries. Schneider et al. originally described a series of 15 patients with CSS injuries without fracture dislocation, noting the etiology to be acute disc herniations in the young population, and hyperextension injuries with stenosis in the older group. The pathoanatomic etiologies of these injuries are variously attributed to hematomyelia, vascular insult/ischemia (vertebral artery compression), or mechanical injury. On T2-weighted MR studies, hyperintense signals in the cord typically involves the lateral white matter tracts (corticospinal); autopsy specimens further demonstrated axonal and myelin loss in these tracts |
| **Hyperextension Trauma Leads to Central Cord Syndrome**       | Summary: Harrop et al. evaluated traumatic central cord syndromes (TCCS) characterized by incomplete spinal cord injuries.[11] In up to 50% of patients, they were due to hyperextension events in patients with congenital/ degenerative spinal stenosis. Neurological findings were characterized by weakness of the upper vs. lower extremities, variable sensory loss, and bladder dysfunction, with a disproportionate loss of manual dexterity. Notably, the current level of evidence failed to demonstrate a clear correlation between the timing of surgical decompression and improvement in outcomes |
| **Hyperextension CSS Injury of the Cervical Spine and Outcomes**  | Summary: Thompson et al. noted that traumatic hyperextension central cord syndromes (TCCS) are the most common form of an incomplete spinal cord injury especially in patients over 50 years of age with narrowed spinal canals (e.g., documented on plain X-rays and MR).[26] ASIA motor scores (AMS) of ≥60 on admission correlated with 80% rates of walking out of the hospital (e.g., canal diameter of ≥8 mm, 50% clinically improved, and 80% had functional outcomes). However, for AMS of ≤50, there was an 80% chance of not being ambulatory upon discharge, and the need to be transferred to spinal injury rehabilitation centers |
| **Cervical Spine Injuries in Ocean Bathers: Wave-related Accidents** | Summary: Robles evaluated spine injuries resulting from severe aquatic recreational activities; for example, hyperextension injuries resulting in CCSs.[25] The study involved 16 patients (1999 to May 2005) sustaining hyperextension injuries; they were more common for older patients (e.g., with stenosis/spondylosis), but resulted in greater neurological deficits in younger individuals |
| **Pediatric Central Cord Injuries (Child Abuse)**               | Summary: Feldman et al. studied the mechanism of injury in five infants/toddlers who sustained cervical spinal cord injuries associated with brain injuries that resulting in paralysis and CCSs (e.g., decreased upper but with relatively preserved lower extremity function). Typically MR studies most clearly documented the extent/ severity of cord injury often without bony trauma (e.g., as in 4 of 5 children with cord injuries without radiological abnormalities) |

Contd...
Table 2: Contd...

| Title of Section | Summaries |
|------------------|-----------|
| CSS After Adequate Decompression for Cervical Spondylosis | Summary: Dickerman et al. presented a case in which a patient developed a CSS following a decompressive C3-C7 cervical laminectomy for cervical stenosis. Following a postoperative fall at a rehabilitation facility, she developed the new-onset of a CSS. As follow-up studies showed no residual cord compression, no further surgery was warranted. Unfortunately, she failed to regain substantial neurological function. |
| Central Cord Injury With Klippel-Feil Syndrome | Summary: Epstein et al. discussed the onset of traumatic myelopathy attributed to a hyperextension injury incurred when a 17-year-old male with a C2-C3 Klippel-Feil congenital fusion and stenosis was body surfing. The plain X-rays and CT studies revealed no fracture/dislocation, and therefore, no surgical lesion. Despite his original quadriplegia, the patient fully recovered without surgical intervention. |
| OTHER ETIOLOGIES OF CENTRAL CORD INJURIES | Summary: In this case report, Lee et al. noted that a 25-year-old male sustained a CCS after status epilepticus. Notably, the cervical MRI showed a hyperintense signal in the cord opposite the C1 level without other pathology, and the patient was managed nonsurgically. Theoretically the seizures produced the CSS injury due to (1) traction/stretch injuries with acute narrowing of the canal in hyperextension, (2) temporary bulging of the discs, and (3) transient vertebral subluxation. |
| CSS After Total Hip Replacement | Summary: Buchowski et al. presented a case in which a patient sustained a CSS following a total hip replacement performed under general endotracheal anesthesia. When the postoperative MR scan showed marked cervical cord compression the patient had an emergent cervical laminectomy. The authors concluded that it is important to evaluate the cervical spine and avoid cervical hyperextension during intubation in older patients who have a higher incidence of stenosis/spondylosis. |
| Acute/subacute Spinal Epidural Hematoma Resulting in CSS | Summary: Yu et al. looked at the diagnosis/treatment of spinal epidural hematomas in 11 patients, 2 of who had clots in the cervical spine, and 2 at the cervico-thoracic junction. Notably, three patients were quadriplegic, and one had a CCS. All four patients with cervical disease underwent emergent open-door laminoplasty accompanied by hematoma removal/drainage; all improved postoperatively. |
| DIFFERENTIAL DIAGNOSES OF CENTRAL CORD SYNDROMES | Summary: Karim and Majithia described Devic’s syndrome/neuromyelitis optica (NMO) as an “inflammatory demyelinating disease of the central nervous system (CNS) associated with optic neuritis.” They reported a 22-year-old African American female, 22 weeks pregnant, who presented with quadriplegia, horizontal diplopia, temporal headache, and arthralgias. The brain, cervical and thoracic MR scans show abnormal intrinsic signals, and the diagnosis of Devic’s syndrome with systemic lupus erythematosus (SLE) was established and managed with pulse IV solumedrol and plasmapheresis for 4 days, she improved. |
| Devic’s Syndrome: Initial Presentation of Systemic Lupus Erythematosus | Summary: Alhomoud et al. described the clinical, laboratory, and radiological features of Primary Sjogren’s syndrome (PSS) presenting within the CNS involvement. For 12 females with PSS and CNS, averaging 40 years of age, 8 had myelopathy, 9 had optic neuritis, while spine MRIs demonstrated “multiple foci of hyperintensity on T2-weighted images (6 patients), and 2 showed long segments of hyperintensity in the cervical spinal cord Lesions on MR were segmented; cervical spinal cord atrophy showed the highest correlation with physical disability in MS. |
| Multiple Sclerosis; MRI-defined Spinal Cord Involvement/Disability in MS | Summary: For MS patients, Cohen et al. correlated MRI-defined lesions, atrophy, and other pathology reflecting brain/spinal cord involvement with disability. Cervical spinal cord contour volumes and cord T2 hyperintense lesions on MR were segmented; cervical spinal cord atrophy showed the highest correlation with physical disability in MS. |
| RADIOGRAPHIC STUDIES CORRELATION WITH CSS | Summary: Song et al. described the clinical/prognostic value of dynamic X-rays and MR studies in 23 patients with CCS without fracture/dislocation. They evaluated multiple X-rays and MR factors including prevertebral hyperintensity (HI), cord compression, intramedullary high-signal intensity (IMHSI), with/without instability. Of interest, prevertebral HI was noted in 17 patients (11 with instability; 19 with cord compression). Neurological deficits also closely correlated with the level of instability (100%), and on MR, IMHSI (95%), and cord compression (87%). |
| Cervical Spine Trauma Clearance: Are Multidetector CT Scans Sufficient? | Summary: Chew et al. observed that clearing the cervical spine following trauma is critical. Although the neurological exam alone may be sufficient in intact patients without neck pain, those with neck pain, altered levels of cognition/consciousness, require further assessment. Of 1004 patients (614 males averaging 47 years of age), 662 MR studies were performed for neck pain, 467 for altered mental status, and 157 for neurological signs or symptoms. The authors concluded that MR scans documented clinically irrelevant ligamentous injury when MDCT were normal (rate of 97-100%); notably, none of these patients required surgery or a halo bracing. Of interest, 39 patients required surgery (e.g., 29 anterior, 10 posterior) at some point, and 5 of the 39 with CSS underwent delayed operations. |
| Acute CSS: Rare Anterior Spinal Artery Syndromes on CT Angiography | Summary: Zhang et al. studied the incidence of anterior spinal artery (ASA) rupture following 20 SCI largely attributed to blunt injuries (except 1 stab wound): 10 with CCS, 4 with Brown-Sequard syndromes (BSS) and six quadriplegic patients (ASIA A). Computed Tomographic Angiography (CTA) revealed; no ASA in CCS/BSS patients, and only one ASA in a patient following a stab-wound. |
| SCORING SYSTEM FOR SPINAL CORD INJURY | Summary: Joaquim et al. noted the Subaxial Injury Classification (SLIC) system and severity score facilitated the management of subaxial cervical spine injuries. SLIC scores of 1-3 points were managed without surgery, SLIC scores of 4 points including those with central cord injuries with incomplete neurologic deficits were treated conservatively or operatively, while SLIC scores of 5-10 points were largely managed surgically. |
Table 2: Contd...

| Title of Section | Summaries |
|------------------|-----------|
| MEDICAL COMPLICATIONS OF CENTRAL CORD SYNDROME | Summary: Onmez et al. presented the case of a 51-year-old female with a central cord injury who developed bilateral upper-extremity DVT; she was successfully medically managed, and the bilateral thrombus regressed. The authors concluded that both editor nonsurgically Page 16 of 21 and those managed surgically could have a favorable outcome. |
| CONSERVATIVE MANAGEMENT OF CSS | Summary: Stevens et al. reviewed the recommendations for conservative treatment (59 patients) vs. surgery (67 patients), timing of surgery (16 ± 24 h, 34 ± 24 h, or 17 delayed second admission), outcomes (Frankel Grade), length of stay (LOS; intensive care unit) for 126 patients who sustained TCSSs between 1985 and 2006. Patients were followed an average of 32 months (1-210 months). Those managed surgically improved an average of one Frankel grade vs. those treated medically, but the timing of surgery did not appear to correlate with any significant difference/improvement in neurologic outcomes (Frankel Grades). The authors concluded a “prospective randomized controlled trial is needed to definitively compare surgical versus medical management and/or early versus delayed surgical treatment in the setting of traumatic CCS” |
| Trends in Management of Central Cord Syndrome in 16,134 Patients | Summary: Brodell et al. evaluated the treatment (surgical/nonsurgical) for 16,134 patients obtained from the Nationwide Inpatient Sample (NIS) 2003-2010 following traumatic cervical CSS. Utilizing ICD9-CM codes, 39.7% of patients (6351) had surgery; anterior cervical decompression and fusion (19.4% ACDF), posterior cervical decompression and fusion (PCDF 7.4%), and posterior cervical decompression (6.8% PCD). Notably over the 7-year course of this study, the frequency of surgical treatment increased an average of 40% per year. Of interest, in-patient mortality (2.6%) was variously attributed to increased age, a greater number of comorbidities, lower surgical rates, treatment in more rural hospitals, and lower patient incomes |
| Laminoplasty vs. Conservative Treatment of CSS Due to OPLL | Summary: Gu et al. evaluated how patients with OPLL who sustained spinal cord injuries exhibit better outcomes following laminoplasty vs. conservative treatment. Surgical patients exhibited shorter LOS, better motor/sensory outcomes, fewer complications, increased canal diameters/reduced occupation ratios/reduced high intrinsic cord signals on T2-weighted MR images at 6 months, without loss of lordosis or range of motion vs. those managed nonsurgically. |
| Acute Traumatic CSS Treated with Open-door Expansile Cervical Laminoplasty | Summary: Uribe et al. evaluated the efficacy of open-door expansile cervical laminoplasty (ODECL) in the management of CSS attributed to multilevel cervical spondylotic myelopathy. Over 3 years, 29 of 69 patients with cervical spinal cord injuries had acute traumatic cord syndromes (ATCCS). For the 15 undergoing expansile cervical laminoplasty (within an average of 3 days following trauma), surgery proved to be safe and effective, resulted in no postoperative deterioration, and in fact, a 71.4% (incidence of improvement 1 ASIA grade (e.g., within 3 postoperative months) |
| Surgery for Acute Subaxial Traumatic CSS Without Fracture or Dislocation | Summary: Song et al. evaluated 22 patients with subaxial acute traumatic CCS without fracture or dislocation who required spinal surgery. Pathology (dynamic cervical X-rays and MR studies) included; cervical cord compression (22 patients), instability (11 patients), disc herniations (7 patients), cervical spondylody (11 patients), and OPLL (4 patients). None deteriorated following anterior decompression/fusion (12 patients), posterior decompression/fusion (11 patients), and 1 re-operation was performed an average of 8 days following the injury |
| TIMING OF SURGERY AND OUTCOMES FOR CSS | Summary: Aarabi et al. evaluated 1-year outcomes of surgery performed in 42 of 59 patients with acute traumatic central cord syndromes (ATCCS) attributed to spinal stenosis. For these patients, compression was most severe at the C3-4 and C4-5 levels (71%; canal measured 5.6 mm). Additionally, the maximal canal compromise (MCC) was 50.5%, and the length of parenchymal damage (T2-weighted MR) was typically 29.4 mm. The intervals between injury and surgery varied from 24 h (9 patients) to 24-48 h (10 patients), and >48 h (23 patients). Major factors determining the quality of long-term outcomes included admission AMS, mid-sagittal canal diameter, (% of MCC), the length of the intrinsic high cord signal (MR), and age |
| Urgency of Early Surgical Decompression in Acute CSS with Stenosis | Summary: Lenehan et al. evaluated whether urgent surgical decompression facilitates neurologic recovery following acute central cord injuries without attendant fracture/dislocation. They found that early surgery “resulted in a 6.31 point greater improvement in total motor score than did the late surgery group.” They concluded that it is “reasonable and safe to consider early surgical decompression in patients with profound neurologic deficit (ASIA=C) and persistent spinal cord compression due to developmental cervical spinal canal stenosis without fracture or instability.” Alternatively, for those with lesser deficits (ASIA=D) initial treatment may be nonsurgical, but surgery may be considered at a later date |
| Early Surgery for Spinal Cord Injury, Especially for Incomplete CSS | Summary: Fehlings et al. utilized a 20-question survey of 971 spinal surgeons (orthopedic and neurosurgeons) worldwide regarding the optimal timing of surgery (early 24 h vs. later decompression) for acute SCI. They recommended that both complete and incomplete cervical SCI be decompressed within 6 h (46.2% and 72.9%, respectively), except for patients with CSSs |
| Incidence and Outcomes of Acute CSS and Other Clinical Syndromes | Summary: McKinley et al. examined outcomes for patients sustaining spinal cord injury associated with CSS, Brown-Sequard (BSS), anterior cord (ACS), posterior cord (PCS), cauda equina (CES), and conus medullaris (CMS) syndromes. They evaluated 175 patients (20.9%) who had SCI clinical syndromes; CSS (44%) was most commonly noted; followed by CES (25.1%), and BSS (17.1%). Of interest, CSS patients were typically in the older age group and exhibited the poorest functional levels/outcomes |
ETIOLOGY OF CENTRAL CORD INJURIES

CSS: Traumatic myelopathy in patients with stenosis without fracture/dislocation

Epstein et al., in 1980, published one of the first articles observing the incidence of traumatic myelopathy occurring in patients with cervical spinal stenosis without fracture or dislocation [Table 2]. They specified that in patients with traumatic hyperextension injuries resulting in CCSs [10]. Their study looked at the subset of patients from a spinal cord injury (SCI) study in which no specific lesion could be identified utilizing X-ray and CT studies (MR not yet available) to define the etiology of patient’s CSS [Figures 1–6].

Central cord injury: Pathophysiology, management, and outcomes

Harrop et al. utilized Medline to evaluate the pathophysiology, management, and outcomes of acute traumatic central cord syndromes (ATCCSs)/injuries (CSS) [Table 2]. ATCCS are the most frequent cause of incomplete traumatic cord injuries. Schneider et al. originally defined this syndrome in 1954, citing the predominant hyperextension mechanism in the absence of fracture/dislocation following various traumatic events (e.g., motor vehicle accidents, falls, and diving injuries). His definition included the greater upper vs. lower extremity motor deficits, the presence of bladder dysfunction, and variable sensory below the lumbosacral canal. His study included a review of 15 patients who presented with minor or major cervical injuries, in patients ranging in age from 18 to 85. Most injuries were attributed to acute mechanical compression attributed to hyperextension, resulting in the “pincher compression” of the cord between the spondylotic osteophytes anteriorly and acute inward buckling of the yellow ligament posteriorly. However, in younger patients, their deficits could be attributed to acute disc herniations without the stenotic findings.

Pathoanatomic etiologies of ATCCS injuries were variously attributed to: Hematomyelia (worse injury/poor prognostic finding), vascular insult/ischemia (vertebral compression), or mechanical injury. T2-weighted MR studies typically demonstrate hyperintense signals in the cord tissues involving the lateral white matter tracts (corticospinal) with accompanying axonal and myelin loss (the latter confirmed on autopsy).

Acute traumatic CSS; clinical and radiological correlations

Miranda et al. correlated neurological impairment and radiological findings for 15 patients who sustained acute traumatic CSS [Table 2]. Global motor scores were determined for the upper extremities on admission, and an average of 16 months later (6 months to 4 years). Radiographic studies included; plain films, cervical CT and cervical MR; seven had serial MR scans performed. On MR, cervical edema was typically noted, but a few patients also had hemorrhages. Notably, the length of cord edema “significantly correlated with the initial motor score,” while the progressive decrease in T2-weighted hyperintensity in the 7 serial MR studies closely reflected the continued improvement of motor function in the upper extremities.

Hyperextension trauma leads to central cord syndrome

Aarabi et al. evaluated traumatic central cord syndromes (TCCSs) characterized by incomplete spinal cord injuries [Table 2]. In up to 50% of patients, they are due to hyperextension events in those with underlying congenital/degenerative spinal stenosis. Patients exhibited disproportionate weakness of the upper vs. lower extremities, accompanied by variable sensory loss, and bladder dysfunction; over half demonstrated spontaneous improvement of motor deficits, but showed a continued lack of manual dexterity. Notably, the current level of evidence failed to demonstrate a clear correlation between the timing of surgical decompression and improvement in outcomes.

Hyperextension CSS injury of the cervical spine and outcomes

Thompson et al. noted that TCCS is the most common form of an incomplete SCI [Table 2]. It is most frequently encountered in patients over the age of 50 with narrow spinal canals, and is typically correlated with acute hyperextension trauma. Between 2004 and 2008, patients with traumatic hyperextension injuries resulting in CCSs were analyzed utilizing plain radiographs and MR studies.
ASIA motor scores (AMS) of ≥60 on admission correlated with 80% rates of walking out of the hospital. For those with cervical spinal canal diameters of ≥8 mm, 50% demonstrated clinical improvement and 80% exhibited functional outcomes. Alternatively, AMS of ≤50 correlated with an 80% chance of not being able to ambulate at the time of discharge, and correlated with having to be transferred to spinal injury rehabilitation centers.

Cervical spine injuries in ocean bathers: Wave-related accidents
Robles evaluated spine injuries resulting from severe aquatic recreational activities; for example, hyperextension injuries resulting in CCSs [Table 2].[25] His study involved 16 patients (1999 to May 2005) who sustained hyperextension injuries; they were more common in older patients (e.g., with stenosis/spondylosis), but resulted in greater neurological deficits in younger individuals.

Pediatric central cord injuries (child abuse)
Feldman et al. studied the mechanism of injury in five infants/toddlers who sustained cervical spinal cord
injuries (CSSs) associated with brain injuries resulting in paralysis [Table 2]. Their deficits were characterized by decreased upper, but relatively unimpeded lower extremity function. Typically, the performance of cervical MR studies was delayed by life support efforts. When obtained, MR scans very clearly documented the extent/severity of SCI that often occurred without bony trauma. Of interest, in this series, four of five children had cord injuries without radiological abnormalities.

CSS after adequate decompression for cervical spondylosis
Dickerman et al. presented a case in which a patient developed a CSS following a decompressive C3-C7 cervical laminectomy for cervical stenosis [Table 2]. Postoperatively, the patient’s spasticity/gait improved, and she was discharged to an inpatient rehabilitation center to treat her residual upper extremity weakness. Following a fall, however, she developed the new onset of a CSS. However, since her studies showed adequate canal decompression, no further surgery was performed, and she failed to demonstrate any substantial improvement.

Central cord injury with Klippel–Feil syndrome
Epstein et al. discussed the onset of traumatic myelopathy attributed to a hyperextension injury incurred when a 17-year-old male with a C2-C3 Klippel–Feil (KL) congenital fusion/stenosis was body surfing [Table 2]. The plain X-rays and CT studies revealed no fracture/dislocation, and therefore, no surgical lesion. Despite his original quadriplegia, the patient fully recovered without surgical intervention.

CSS-related status epilepticus: A case report
In this case report, Lee et al. noted that a 25-year-old male sustained a CCS after status epilepticus [Table 2]. Notably, the cervical MRI showed a hyperintense signal in the cord opposite the C1 level without other pathology; the patient, managed nonsurgically, improved on the AMS and regained bladder function. The CSS injury was attributed to muscle contractions occurring during generalized seizures. Theoretically the seizures produced (i) traction/stretch injuries with acute narrowing of the canal in hyperextension, (ii) temporary bulging of the discs, and/or (iii) transient vertebral subluxation.

CSS after total hip replacement
Buchowski et al. presented a case in which a patient sustained a CSS following a total hip replacement performed under general endotracheal anesthesia [Table 2]. When the postoperative MR scan showed marked cervical cord compression, the patient had an emergent cervical laminectomy. The authors concluded that it is important to evaluate the cervical spine and avoid cervical hyperextension during intubation in older patients who have a higher incidence of stenosis/spondylosis.
Acute/subacute spinal epidural hematoma resulting in CSS

Yu et al. looked at the diagnosis/treatment of spinal epidural hematomas in 11 patients; 2 had clots in the cervical spine, and 2 at the cervico-thoracic junction [Table 2].\(^{[31]}\) Notably, three patients were quadriplegic, and one had a CCS. MRI studies showed equal intensity/hyperintensity on T1-weighted images, and mixed hyperintensity on T2-weighted images. All four patients underwent emergent open-door laminoplasty accompanied by hematoma removal/drainage; all improved postoperatively. The authors concluded that since the physical and MRI findings correlated with acute/subacute spinal epidural hematomas, emergent surgical intervention to facilitate maximal recovery was warranted.

DIFFERENTIAL DIAGNOSES OF CENTRAL CORD SYNDROMES

Devic’s syndrome: Initial presentation of systemic lupus erythematosus

Karim and Majithia defined Devic’s syndrome/neuromyelitis optica (NMO) as an “inflammatory demyelinating disease of the central nervous system (CNS) associated with optic neuritis.”\(^{[17]}\) In this report, a 22-year-old African American female, 22 weeks pregnant, presented with the onset of quadripareis, horizontal diplopia, temporal headache, and arthralgias [Table 2]. She exhibited a discoid rash behind the left ear, with motor function of 3/5 in the upper, and 0/5 in the lower extremities. MR scans showed an abnormal signal within the brain, cervical, and thoracic spine. The diagnosis of Devic’s syndrome likely associated with systemic lupus erythematosus (SLE) was established; after treatment with pulse IV solumedrol and plasmapheresis for 4 days, she improved.

Primary sjogren’s syndrome involving the central nervous system

Alhomoud et al. described the clinical, laboratory, and radiological features of primary Sjogren’s syndrome (PSS) presenting within the CNS [Table 2].\(^{[3]}\) In this retrospective analysis of 12 females with PSS and CNS, patients averaged 40 years of age (range 16–58 years), 8 (66%) were myelopathic, 9 (75%) had optic neuritis, 7 (58%) had positive immunological tests (anti-Sjogren’s syndrome A and anti-Sjogren’s syndrome B), and 11 had positive salivary gland biopsies demonstrating inflammatory cell infiltrates. Furthermore, the spine MRIs demonstrated “multiple foci of hyperintensity on T2-weighted image in six patients, and long segments of hyperintensity in the cervical spinal cord in two patients.”

Multiple sclerosis: MRI-defined spinal cord involvement/disability in MS

For multiple sclerosis (MS) patients, Cohen et al. correlated MRI-defined lesions, atrophy, and other pathology reflecting brain/spinal cord involvement with disability [Table 2].\(^{[7]}\) This study involved performing 3T MRIs of the brain/spinal cord in 21 MS patients (18 relapsing-remitting, 1 secondary progressive, and 1 clinically isolated syndrome). Spinal cord contour volumes and cord T2-hyperintense lesions were segmented. They determined that with MR, “only upper cervical spinal cord volumes significantly correlated with Expanded Disability Status Scale scores \((r =−0.515, P = 0.020)\)”. Therefore, cervical spinal cord atrophy showed the highest correlation with physical disability in MS.

RADIOGRAPHIC STUDIES CORRELATION WITH CSS

Hyperintense T2 intramedullary MR signal correlates with CSS

Song et al. assessed the clinical/prognostic value of dynamic X-rays and MR studies in 23 patients with CCS without fracture/dislocation [Table 2].\(^{[28]}\) They evaluated multiple X-rays and MR factors including; prevertebral hyperintensity (HI), cord compression, intramedullary high-signal intensity (IMHSI), with/without instability.\(^{[26]}\) Patients’ outcomes were correlated with their preoperative and postoperative ASIA scores. Surgical intervention included 12 anterior decompressions/fusions (with 1- or 2-level lesions), and 11 posterior decompressions (with multilevel lesions). Of interest, prevertebral HI was noted in 17 patients (11 with instability; 19 with cord compression). Neurological deficits also closely correlated with the level of instability (100%), and on MR, IMHSI (95%), and cord compression (87%).

Cervical spine trauma clearance: Are multidetector CT scans sufficient?

Chew et al. observed that clearing the cervical spine following trauma is critical.\(^{[6]}\) Although the neurological examination alone may be sufficient in intact patients without neck pain, those with neck pain or altered levels of cognition/consciousness require further assessment [Table 2]. Here, the optimal diagnostic management becomes controversial. Do you first order a multidetector CT (MDCT) scan alone, or additionally request an MR to rule out ligamentous/other injuries? In this retrospective analysis from a Level I trauma center, the authors evaluated all patients admitted from January 2004 to June 2011 who underwent MDCT scans (showing no acute traumatic injury) plus cervical MRIs obtained “during the same hospitalization.” Multiple variables were studied; patient demographics, the type of injury,
Glasgow Coma Scale (GCS), when/why an MRI was performed, and whether cervical spine surgery was performed. Of 1004 patients (614 males averaging 47 years of age), 662 MR studies were performed for neck pain, 467 for altered mental status, and 157 for neurological signs or symptoms. MR studies were normal in 645 patients or showed only ligamentous injury in 125 patients; the remainder exhibited only mild degenerative changes. Interestingly, 52.8% were cleared on a clinical basis only (29 on clinical exam and 39 with flexion extension X-rays). The authors concluded that MR scans documented clinically irrelevant ligamentous injury when MDCT were normal (rate of 97–100%); notably, none of these patients required surgery or halo bracing. Of interest, 39 patients required surgery (e.g., 29 anterior, 10 posterior) at some point, and 5 of the 39 with CSS underwent delayed operations.

**Acute CSS: Rare anterior spinal artery syndromes on CT angiography**

Zhang et al. observed that with acute traumatic SCI significant vascular damage may be associated with spinal contusions, fractures, and dislocations [Table 2]. This study specifically evaluated the incidence of anterior spinal artery (ASA) rupture following 20 SCI largely attributed to blunt injuries (except 1 stab wound). Neurological deficits included; 10 with CCS, 4 with Brown–Sequard syndrome (BSS), and 6 with quadriplegia (ASIA A). Computed tomographic angiography (CTA) looking for ASA rupture revealed none in the CCS/BSS patients, and only one ASA in a patient following a stab-wound. The authors concluded CTA readily documents ASA following SCI, but that ASA rupture is rare following acute blunt cervical SCI.

**SCORING SYSTEM FOR SPINAL CORD INJURY**

Cervical injury scoring using a subaxial injury classification system

Joaquim et al. noted that the subaxial injury classification (SLIC) system and severity score facilitates the management of subaxial cervical spine injuries [Table 2]. Utilizing a PubMed database (2007–2014), they correlated the scoring of spinal cord injuries and their ultimate outcomes (e.g. system score). Those with an SLIC score of 1–3 points with spinous process, laminar, or small facet fractures, or those with compression/burst fractures but who were neurologically intact were all conservatively managed (e.g. without surgery). Those with SLIC of 4 points had either incomplete spinal cord injuries (e.g., CCS or compression injuries) with incomplete neurologic deficits, or burst fractures with complete neurologic deficits; these patients were either managed conservatively or with surgery. However, those with SLIC of 5–10 points with distraction/rotational injuries, traumatic disc herniations (with deficits), and burst fractures with incomplete neurologic deficits were largely managed surgically.

**MEDICAL COMPlications OF CENTRAL CORD SYNDROME**

Bilateral upper-extremity deep vein thrombosis after CSS

Onmez et al. evaluated the incidence of deep vein thrombosis (DVT) involving the upper extremities in patients who sustained SCI characterized by CCS [Table 2]. In this case study, a 51-year-old female with a central cord injury developed bilateral upper-extremity DVT; she was successfully medically managed, and the bilateral thrombus regressed. The authors concluded that with this type of SCI, DVT may arise in the upper extremities, and, therefore, prophylactic treatment should be considered.

**CONSERVATIVE VS. SURGICAL MANAGEMENT OF CSS**

Conservative treatment vs. Surgery for traumatic central cord syndrome

Stevens et al. reviewed the recommendations for conservative treatment (59 patients) vs. surgery (67 patients), timing of surgery (<24 h, >24 h, or delayed second admission), outcomes (Frankel Grade), and length of stay (LOS; intensive care unit) for 126 patients who sustained TCSSs between 1985 and 2006 [Tables 1 and 2]. Surgery was performed in 16 patients within 24 h, in 34 patients 24 h after the injury (average 6.7 days later), while 17 had surgery during second hospital admissions (mean interval of 137 days between injury and surgery (range 3–209 days)). Patients were followed an average of 32 months (1–210 months). Although those managed surgically improved an average of one Frankel grade vs. those treated medically, the timing of surgery itself did not correlate with any significant difference/improvement in neurologic outcomes (Frankel Grades). They did, however, observe a “trend toward decreased LOS” particularly for those undergoing surgery during the first hospital stay. Despite similar complication rates for both the surgical/non surgical groups, a “trend toward fewer complications and deaths” for those undergoing surgery within the first 24 h or during the first hospital stay” was observed. The authors concluded that a “prospective randomized controlled trial is needed to definitively compare surgical versus medical management and/or early versus delayed surgical treatment in the setting of traumatic CCS.”
Trends in management of central cord syndrome in 16,134 patients

Brodell et al. evaluated the treatment (surgical vs. nonsurgical) for 16,134 patients following traumatic cervical CCSs [Table 2]. They utilized a retrospective cohort from the Nationwide Inpatient Sample (NIS) 2003–2010 database, and assessed clinical variables, mortality in the hospital, and surgical procedures performed. Utilizing ICD9-CM codes, 39.7% of patients (6351) had surgery; anterior cervical decompression and fusion (ACDF; 19.4%), posterior cervical decompression and fusion (PCDF; 7.4%), and posterior cervical decompression (PCD 6.8%) alone [Figures 7-9]. Notably over the 7-year course of this study, the frequency of surgical treatment increased an average of 40% per year. Of interest, in-patient mortality (2.6%) was variously attributed to increased age, a greater number of comorbidities, lower surgical rates, treatment in more rural hospitals, and lower patient incomes. Notably, surgery for CSS was more common performed in the south, and was more frequently performed at larger institutions.

Laminoplasty vs. Conservative treatment of CSS due to OPLL

Gu et al. evaluated how patients who sustained acute spinal cord injuries following minor trauma (falls, motor vehicle accidents, sports) with underlying ossification of the posterior longitudinal ligament (OPLL: Mostly with mixed and segmental variants) were managed conservatively (C group; 29 patients) or surgically (L group – laminoplasty; 31 patients) [Table 2]. Those undergoing laminoplasty exhibited shorter lengths of stay (LOS), better motor/sensory outcomes, fewer complications, and had increased canal diameters/reduced high intrinsic cord signals on T2-weighted MR images at 6 months vs. those managed conservatively. Nevertheless, the extent of lordosis and range of motion (ROM) were the same for both groups. The authors concluded laminoplasty offers OPLL patients with SCI following minor trauma (e.g. often with CSS) more satisfactory outcomes.

Acute traumatic CSS treated with open-door expansile cervical laminoplasty

Uribe et al. evaluated the efficacy of open-door expansile cervical laminoplasty (ODECL) in the management of CSS attributed to multilevel cervical spondylotic myelopathy [Table 2]. Over 3 years, 29 of 69 cervical spinal cord injuries were due to central cord syndromes (ATCCS) secondary to hyperextension injuries attributed to cervical spondylosis/stenosis without fracture/dislocation, or instability. Expansile cervical laminoplasty was performed in 15 patients (averaging 56 years of age) typically within 3 days of injury; it proved not only to be safe and effective, resulting in no postoperative neurological deterioration, but also 71.4% improved 1 ASIA grade within 3 postoperative
Evaluated 22 patients, 13 males and 9 females, averaged 61.2 years of age, and had mostly sustained falls (68%) or motor vehicle accidents (32%).

Pathology, documented on dynamic cervical X-rays and MR studies included cervical cord compression (22 patients), instability (11 patients), disc herniations (7 patients), cervical spondylosis (11 patients), and OPLL (4 patients). Anterior decompression/fusion (12 patients; 1- or 2-level lesions), posterior decompression/fusion (11 patients; multilevel lesions), and 1 re-operation were performed an average of 8 days following the injury (range 1–37 days). Postoperatively, all patients improved, and none exhibited further deterioration.

**TIMING OF SURGERY AND OUTCOMES FOR CSS**

**Outcomes for acute traumatic central cord syndrome due to spinal stenosis**

Aarabi et al. evaluated multiple variables impacting the 1-year postoperative outcomes for patients sustaining ATCCSs attributed to spinal stenosis [Table 2].[2] Variables studied included clinical data, an evaluation of injury severity measures (e.g. imaging studies), AMS, functional independence measure (FIM), manual dexterity, and dysesthetic pain scores. Over 100 months, out of 211 patients with ATCCS, 59 with spinal stenosis underwent surgical decompressions; 5 died, 2 were lost to follow-up, 10 were not eligible for the study, while the remaining 42 were followed for at least 12 months. Patients averaged 58.3 years of age, 83% were male, and 52.4% of accidents involved falls. The mean admission AMS was 63.8 (upper extremities 23.8, lower extremities 39.8). Most frequently, cord compression was documented at the C3-4 and C4-5 (71%) levels, and the canal typically measured only 5.6 mm. Additionally, the following measurements were obtained; the extent of maximum canal compromise (MCC) of 50.5%, maximum spinal cord compression of 16.5%, and length of parenchymal damage (T2-weighted MR) of 29.4 mm. The intervals between injury and surgery varied; within 24 h (9 patients), 24–48 h (10 patients), and >48 h (23 patients). One year postoperatively, the mean AMS was 94.1 (upper extremities 45.7, lower extremities 47.6), FIM (111.1), manual dexterity (64.4% of baseline), and pain (3.5). The major factors determining the quality of long-term outcomes included admission AMS, mid-sagittal canal diameter, percentage of MCC, length of intrinsic high cord signal (MR), and the patient’s age.

**Urgency of early surgical decompression in acute CSS with stenosis**

Lenehan et al. evaluated whether urgent surgical decompression facilitates neurologic recovery following acute central cord injuries without attendant fracture/dislocation [Tables 1 and 2].[10] They reviewed whether the following variables impacted outcome; demographic data, mechanism of injury, comorbidities, neurologic status, and surgery. Outcomes (obtained on admission, discharge, 6 and 12 months later) utilized the following measures: AMS, ASIA Grade, FIM Score, SF-36, Sphincter Disturbance, and Ambulatory status. They concluded that early surgery “resulted in a 6.31 point greater improvement in total motor score than did the late surgery group.” At 6 months, early surgery (within 24 h; 7.79 U more improvement in FIM total Score) showed greater improvement in the ASIA Grade vs. late surgery; this increased further at 12 months. The authors concluded that it is “reasonable and safe to consider early surgical decompression in patients with profound neurologic deficit (ASIA = C) and persistent spinal cord compression due to developmental cervical spinal canal stenosis without fracture or instability.” Alternatively, patients with lesser deficits (ASIA = D) may be initially followed conservatively, reserving surgery for later if indicated.

**Early surgery for spinal cord injury, especially for incomplete CSS**

Fehlings et al. evaluated the optimal timing of surgery (early vs. later decompression) for acute SCI [Table 2].[12] They utilized a 20-question survey.
evaluated by 971 orthopedic and neurosurgical spine surgeons worldwide. They found that spine surgeons recommended that both complete and incomplete cervical SCI should be decompressed within 6 h (46.2% and 72.9%, respectively). “In almost every clinical scenario, with the exception of CCS, the majority of respondents (≥80%) preferred to decompress the spinal cord within 24 h”; in fact, many favored decompression within 12 h especially for patients with incomplete deficits except for those with CCSs [Table 1].

Incidence and outcomes of acute CSS and other clinical syndromes
McKinley et al. examined the factors correlating with outcomes for patients sustaining SCI associated with CSS, BSS, anterior cord syndrome (ACS), posterior cord syndrome (PCS), cauda equina syndrome (CES), and conus medullaris syndrome (CMS) [Table 2].[21] They evaluated 175 patients who had SCI clinical syndromes; CSS (44%) was most commonly noted, followed by CES (25.1%), and BSS (17.1%). Notably, those with acute CSS were typically in the older age group and exhibited the poorest functional outcomes.

Factors predicting motor recovery and outcome after traumatic CSS
For patients who sustained traumatic CSS, Dvorak et al. prospectively assessed improvement in AMS (at 72 h and follow-up), generic health-related quality of life (HRQoL), and functional status [Table 2].[9] AMS improved from 58.7 to 92.3; although 81% of patients exhibited residual incontinence, 96% ambulated without assistance. Better functional status (FIM) and improved outcomes (HRQoL) reflected higher initial AMS scores, higher levels of formal education, the lack of comorbidities, and younger age.

SUMMARY
Although the treatment strategies for CSS remain controversial, establishing the diagnosis of CSS has been greatly facilitated with the ready availability of CT and MR studies [Tables 1 and 2]. After first obtaining negative CT scans (demonstrating no fracture, dislocation, or instability), MR studies now readily demonstrate hyperintense T2 signals in the cord indicative of edema and more rarely hematomyelia (within 12 h especially for patients with incomplete deficits except for those with CCSs) [Table 1]. Decisions regarding nonsurgical vs. surgical options depend upon multiple factors; the severity of the neurological deficit, whether the deficit has spontaneous improved or it is has plateaued, and the severity of cord compromise. For those with mild deficits or where deficits have substantially improved/plateaued, without significant cord compromise, nonsurgical options may be chosen, followed choices for delayed surgery or rarely, acute surgery. Alternatively, for those with moderate/severe deficits who have not improved in the presence of marked cord compromise, operative choices typically factor acute surgery, followed by delayed surgery, and, only rarely, no surgery (e.g. other extenuating factors).

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