MANAGEMENT OF ACUTE CENTRAL CERVICAL SPINAL CORD INJURIES

RECOMMENDATIONS

Standards: There is insufficient evidence to support treatment standards.

Guidelines: There is insufficient evidence to support treatment standards.

Options:

- Intensive care unit (or other monitored setting) management of patients with acute central cervical spinal cord injuries (ACCSCI), particularly patients with severe neurological deficits, is recommended.
- Medical management including cardiac, hemodynamic and respiratory monitoring, and maintenance of mean arterial blood pressure at 85 – 90 mm Hg for the first week after injury to improve spinal cord perfusion, is recommended.
- Early reduction of fracture dislocation injuries is recommended.
- Surgical decompression of the compressed spinal cord, particularly if the compression is focal and anterior, is recommended.

RATIONALE

Central spinal cord injuries are among the most common, well-recognized spinal cord injury patterns identified in neurologically injured patients after acute trauma. Originally described by Richard Schneider in 1954, this pattern of neurologically incomplete spinal cord injury is characterized by "disproportionately more motor impairment of the upper than of the lower extremities, bladder dysfunction and varying degrees of sensory loss below the level of the lesion".(19) It has been associated with hyperextension injuries of the cervical spine, even without apparent damage to the bony spine, but has also been described in association with vertebral body fractures and fracture-dislocation injuries. The natural history of acute central

cervical spinal cord injuries indicates gradual recovery of neurological function for most patients, albeit usually incomplete and related to the severity of the original injury and the age of the patient.(4,12,15,17-19,21) The role of surgery and its timing for patients with acute central spinal cord injuries without fracture compression or dislocation injuries are the subjects of considerable debate.(3,5-8,18,19) The optimal management of patients who have sustained acute central cervical spinal cord injuries is the subject of these recommendations.

SEARCH CRITERIA

A National Library of Medicine computerized literature search from 1966 to 2001 was undertaken using Medical Subject Headings in combination with "spinal cord injury": "central cord syndrome" and "incomplete cervical spinal cord injury". Approximately 1450 citations were acquired. Non English-language citations were excluded. Titles and abstracts of the remaining publications were reviewed and relevant articles were selected to develop the guidelines. We focused on the specific issues of the natural history, medical management and surgical treatment of acute human central cervical spinal cord injuries. These efforts resulted in 13 articles (all Class III studies) specifically describing management and outcomes of patients with central cervical spinal cord injuries. The bibliography includes several articles on Magnetic Resonance (MR) imaging of central cervical spinal cord injuries, multiple articles (all Class III studies) describing series of acute SCI patients, the majority of whom had incomplete cervical spinal cord injuries and several general review articles that address issues of acute spinal cord injuries, including pathophysiology and treatment. The 13 case series describing the management of patients with acute central cervical spinal cord injuries are summarized in Evidentiary Table format.

SCIENTIFIC FOUNDATION

In 1951, Schneider described two patients with acute neurologically incomplete cervical spinal cord injuries for whom he suggested that early operation was indicated.(20) Both patients presented with sudden loss of motor function in the distal upper extremities, in the torso and lower extremities, but had preservation of touch and vibration sense following trauma. Both patients had anterior spinal cord compression from acute traumatic cervical disc herniations (one had an associated vertebral endplate fracture). The diagnosis and anatomic localization were based on the clinical examination. Both patients made incomplete but significant neurological recoveries following delayed surgical decompression via laminectomy, dentate ligament sectioning and transdural discectomy. Three years later Schneider, Cherry and Pantek described eight patients they managed along with six other patients culled from the available literature.(19) All but two of these patients presented with disproportionately more motor impairment in the upper extremities than in the lower extremities, bladder dysfunction with retention, and varying degrees of sensory loss below the level of the lesion. Two of the six patients identified in the literature review had complete motor injuries in both the upper and lower extremities, with some preservation of sensory function below the level of injury. These incomplete neurological deficits were related to acute traumatic central cervical spinal cord injuries, usually, but not exclusively, as a result of hyperextension of the head and neck relative to the torso. In several patients there was no damage to the bony spine. In these instances it was presumed that hypertrophic changes (spurs, ridges, thickened ligaments) within the spinal canal caused anterior and posterior cord compression in the position of hyperextension, resulting in injury to the central substance of the cervical spinal cord. Other patients had cervical compression fractures

or fracture-dislocation injuries of the cervical spine that contributed to the central spinal cord injury.

The authors operated on the first two of the eight patients they treated with this disorder. Both had central cervical spinal cord injuries without bony damage or displacement. Both were treated in delayed fashion via laminectomy with sectioning of the dentate ligaments followed by transdural exploration anterior to the cervical spinal cord. In both cases anterior bony osteophytes were identified but were not removed. Patient #1 was quadriplegic postoperatively. Patient #2 was neither better nor worse following surgery. Six additional consecutive patients were managed without surgical decompression, (#7 underwent delayed dorsal cervical fusion in treatment of fracture instability). Five of six patients they managed expectantly, (patient #4 had progression of neurological deficits despite immobilization and ultimately died three weeks after injury), and three of six patients from the literature improved without surgery, (75%). The majority experienced permanent loss of hand function and strength. One of six patients from their series and three of six from the literature died without neurological recovery (25%). Conversely, one of two patients treated surgically was immediately neurologically worse (50%), the second made a progressive albeit incomplete recovery over time, (50%), much like that observed in comparative patients managed without surgery. It was on the basis of this early experience that Schneider and colleagues determined that the prognosis following acute central cervical spinal cord injury was reasonably good. Surgery for these patients they concluded was "contraindicated" and "in fact known to harm… rather than improve them".

In 1958 Schneider, Thompson and Bebin added observations on 12 additional patients they managed with acute central cervical spinal cord injuries.(18) One patient died of pneumonia without neurological recovery, one patient had a full neurological recovery, the

remaining ten improved compared to their initial post-injury neurological status, but were profoundly impaired at last follow-up. They noted two distinct age groups with acute central cervical spinal cord injuries. They described an older group of patients (mean age 59 years) without bony vertebral damage but with hypertrophic changes compromising the cervical spinal canal, and a younger group (mean age 31 years) with fracture or fracture dislocation injuries of the cervical spine. They reported that central cord edema, venous congestion and ischemia were components of the pathophysiology of this unique injury type. They advocated expectant management, including closed reduction with skeletal traction (four patients), for all patients with this syndrome, despite important, near-complete neurological recovery in a 17-year-old patient after operative reduction and decompression of a unilateral facet dislocation injury within 13 hours of injury.

Schneider's collective reported personal experience with the management of patients with acute central cervical cord injuries to date numbered 20 patients.(18) Of the 20, 17 were managed medically: two died without improvement, 14 improved but had profound residual deficits and one patient regained normal function. Three patients were treated with surgical decompression: one early (hours) and two late (weeks). The patient with early decompression improved dramatically. One late decompression patient neither improved nor worsened immediately after surgery but showed progressive long-term improvement, the other was quadriplegic after surgery. From this experience they concluded, "accurate diagnosis is stressed, with emphasis placed on the fact that operation is contraindicated, that the prognosis may be good and that should recovery occur it will follow a definite pattern". These suggestions have guided the care of acute central cervical spinal cord injury patients ever since.

In 1971 Bosch et al described observations made during their management of 42 patients with subacute central cervical spinal cord injuries they treated at a rehabilitation hospital and provided four month to 26 year follow-up.(2) At admission 19% were independent ambulators, 14% were partial ambulators and 67% could not ambulate. Twenty six per cent had functional hands upon admission. Upon discharge 57% had functional ambulation skills, 20% were partial ambulators and 42% had functional hands. Bladder control improved from 17% upon admission to 53% upon discharge. A similar improvement in bowel control was documented. Importantly, these authors noted late deterioration in 24% of patients who showed initial improvements in neurological function after central cervical spinal cord injury. Ten of 42 patients (24%) experienced the late neurological sequelae of "chronic central cord syndrome" and lost ambulation, hand and bladder control skills in long-term follow-up. The authors concluded that at least some return of neurological function in the immediate post-injury period could be expected in about 75% of cases, with 56% of patients regaining functional hands. Long term, only 59% of patients with central cervical spinal cord injuries they followed retained functional skills with conventional medical management.

In the same year, Turnbull presented his studies on the microvasculature of the human spinal cord and postulated as to the mechanisms of vascular insufficiency associated with various types of spinal cord displacement.(27) His work speaks to the anatomical basis of the pathophysiology of acute cervical central spinal cord injuries, particularly those which occur in older patients with underlying cervical spondylosis who sustain acute central SCI without bony vertebral injury. He found that as the cord becomes compressed, whether due to a mass lesion or progressive cervical spondylosis, it becomes flattened and widened. The vasculature of the cord is affected by cord distortion. Pial vessels become more tortuous. Arteries of the lateral columns

are elongated, narrowed and flattened. Branches from the central arteries that reach the gray matter run laterally and are similarly stretched lengthwise and are compressed from side to side. Turnbull reported that vessels chronically deformed by cervical spondylosis cannot respond to additional anteroposterior flattening of the cord as would normal arteries in a younger patient. "A little additional compression would pinch off side branches at their origins". He concluded that mechanical distortion of the cord and its blood supply plays a major role in the pathophysiology of spinal disease and spinal cord injury. (26,27,28)

In 1977, Shrosbree reported 99 patients with acute central cervical spinal cord injuries managed at a South African Spinal Cord Injury Centre, the majority of whom were admitted within 72 hours of injury.(21) All patients were treated conservatively. Fracture/injury reduction was accomplished via closed means in 92% of patients with dislocation, either by traction or by reduction under anesthesia, within 72 hours of admission. Two age groups of patients were identified. Younger patients (21 to 50 years) had flexion rotation injuries and a higher incidence of dislocation injuries. Older patients (50 years and above) were more likely to have hyperextension injuries superimposed on preexisting cervical spondylosis. Outcome was related to the severity of the initial neurological deficit. Only five of 23 patients (22%) with severe motor deficits became independent ambulators. All of these patients had residual deficits in the hands. The author summarized by noting that "early reduction may well be a factor in promoting more favorable neurological recovery" among patients with facet dislocation injuries, but gave no data to support his claim.

In 1977, Maroon reported that "burning hands", severe dysesthesias in the hands and fingers following trauma despite normal motor function may indicate acute central spinal cord injury.(13) He described two football players with dysesthetic symptoms in the hands referable

to modest injury to the central cervical spinal cord and warned physicians, trainers and coaches of the importance of this syndrome.

In 1980, Brodkey and associates revisited the management of the acute central cervical spinal cord injury syndrome.(5) They provided operative treatment to seven patients with traumatic central cervical spinal cord injuries within 18 to 45 days after acute injury that had profound residual neurological deficits after attentive medical treatment. These patients all had significant defects on myelography. Four patients underwent anterior cervical discectomy with fusion (ACDF), one was treated with multilevel laminectomy, one had multilevel ACDF and one received multilevel laminectomy followed by delayed (four years) multilevel ACDF. All patients had accelerated neurological recoveries following each surgical procedure, even the patient who deteriorated years after laminectomy and required late multilevel ACDF. Three patients returned to normal after severe injuries that persisted until surgical decompression. The authors concluded that cord compression does play an important role in the pathophysiology of central cord syndrome and that when present, in the setting of a stable poor neurological condition following injury, that decompression of the spinal cord may be of benefit.

Bose et al retrospectively analyzed their management of 28 patients with acute central cervical spinal cord injuries.(3) In their 1984 report, they noted significantly improved motor scores at time of discharge in patients managed with combined medical therapy and surgery, compared to those managed medically alone. All were treated aggressively in the ICU setting. Surgical patients had myelographic evidence of cord compression or evidence of cervical spinal instability. While selection bias (surgical patients had cord compression and/or instability or subluxation), and several other study flaws precluded direct comparison between the groups, the authors noted that no surgical patient worsened as a result of surgery and all improved

neurologically, several substantially. They argued that decompression of the compressed spinal cord in patients with acute central cervical spinal cord injury syndrome may be of benefit in selected patients.

Merriam et al, Roth et al, Bridle et al and Newey, Sen and Fraser each described the late outcomes of individual series of selected groups of patients following central cervical spinal cord injury.(4,12,15,17) All four groups of investigators noted marked heterogeneity among patients in the central cervical spinal cord injury population. All patients were managed medically. Most patients improved somewhat over time, with more recovery in the lower extremities than in the upper extremities. All concluded that outcome was in general good for patients less than 70 years of age; the final neurological result was influenced by patient age, particularly age over 70 years, and the degree of initial neurological impairment. Hand function impairment was the most common long-term disability, even among patients with a "good" outcome. Only Merriam et al made reference to surgical treatment, involving 30 of 77 patients in their series, presumably to provide spinal stabilization and fusion.(12) No association between surgical management and outcome was discerned.

Chen and colleagues reported their experience with 114 patients with acute and chronic traumatic central cervical cord syndrome.(7) Twenty-eight patients were managed with surgical treatment, 86 were managed medically. The authors did not randomize patients to one treatment group or another. Selection criteria for surgical decompression included failure to improve with medical therapy or deterioration in neurological function despite medical treatment with radiographic (MRI or CT/myelography) evidence of focal cord compression, or gross instability of the spine. They operated on three patients late (8, 12 and 24 months post-injury) for "chronic" central cord syndrome. Their 1997 retrospective review found that younger patients had better

long-term results than did older patients (in both management groups), and that surgical decompression was associated with more rapid and complete motor improvement compared to patients managed medically, even if operated late after injury. Both management groups had similar outcomes over time with respect to lower extremity and bladder function. Patients selected for surgery had more rapid and more complete recovery of function, particularly in the upper extremities. The authors noted that patients with stenosis at multiple levels managed conservatively had a poorer prognosis and a relatively higher chance to develop late myelopathy. The authors did not describe the outcome of similar patients with multi-level stenosis managed with operative decompression.

In 1998 Chen et al described the management of 37 patients with pre-existing cervical spondylosis who sustained acute incomplete neurological cervical spinal cord injuries after trauma.(6) Many of these patients had acute central spinal cord injuries. No patient sustained a bony vertebral column injury. In their retrospective review, patients were treated with surgical decompression if they did not improve more than one motor grade within nine days of injury (range three to 14 days). Patients were studied with MRI to document cord compression and/or signal change within the spinal cord. In total, 16 patients underwent surgical decompression, nine anteriorly and seven posteriorly. Twenty-one patients were managed medically. Thirteen of 16 surgical patients (81%) improved "remarkably" immediately after surgery. Thirteen of 21 patients managed medically (62%) improved to the same degree over time. As with surgical patients, patients with cervical stenosis over more than three vertebral levels fared less well than did patients with focal compression or with stenosis over three vertebral levels or fewer. There were no reported differences in outcome between patients in the two groups at two-year follow-up. The authors concluded that surgical decompression might be associated with more rapid

neurological improvement, early mobilization and shorter periods of hospitalization and rehabilitation. They consider MRI as the imaging modality of choice to assess the spinal cord in patients with acute central cervical spinal cord injuries, a conclusion consistent with those of other investigators of the role of MRI in the assessment of patients with spinal cord injuries. (9,14,16,25)

In 2000, Dai and Jia described their experience with 24 patients with acute traumatic disc herniation as the cause of acute central cervical spinal cord injuries.(8) Acute disc herniation was confirmed with pre-operative MRI imaging. The authors provided a retrospective assessment of patients operated upon anteriorly (ACDF without internal fixation) for cord decompression and spinal stabilization. The timing of surgery relative to injury was not described. They noted an inverse correlation between rate of recovery and age and found that patients with fracture dislocation injuries with acute disc herniation were more impaired pre-operatively and fared less well than patients without fracture dislocation injuries at late follow-up. They reported that surgical decompression, stabilization and fusion was successful in all patients and described marked improvement in neurological function in most patients treated.

Contemporary reviews confirm early reports that most patients with incomplete cervical spinal cord injuries meeting the clinical neurological criteria of acute central spinal cord injury will show neurological improvement over time.(2,12,15,17-19,21) Some patients with these injuries will die and many will remain profoundly impaired at late follow-up. These patients in general are older, have spinal cord injuries without bony vertebral injury and have medical co-morbidity, or are younger but have fracture dislocation injuries as a cause of their neurological deficits. A large portion of patients will regain ambulation skills over time but will not have useful hands. A smaller portion of patients will demonstrate significant neurological recovery

and regain hand function. These patients are typically younger, do not have fracture dislocation injuries and have less severe neurological deficits at the outset. Up to 24 percent of patients managed non-operatively will improve early but decline again years later ("chronic central cord injury syndrome").(2)

Surgery for decompression of the spinal cord in patients with acute central cervical spinal cord injuries has been denounced based on Schneider's early poor experience with a single operated patient.(18,19) That patient, quadriplegic after dorsal cervical exploration and decompression, experienced significant manipulation of the injured cord during the process of dentate ligament sectioning and transdural anterior cord exploration, a procedure unlikely to be performed in similar fashion today.(19) The same group had a rewarding experience with early, (13 hours after injury), surgical decompression and facet fracture reduction in a 17-year-old male with profound early central cord neurological deficits.(18) Multiple other authors, including three contemporary series of patients with this disorder, have described good to excellent outcomes without neurological complications for surgical decompression of patients with spinal cord compression, particularly focal anterior cord compression.(3,5-8) However, no study to date has provided a randomized direct comparison of surgical patients to similar patients managed without surgery. Nor has any study adequately assessed the potential role of dorsal spinal decompression for multi-level cervical cord compression in patients with this disorder, particularly those with acute central cervical cord syndrome without bony vertebral damage. Surgery may have a role in the management of patients with acute central cervical spinal cord injury, but as yet that role has not been accurately defined by scientific study.

Schneider's conclusion that central cord edema, venous congestion and ischemia were important components of the pathophysiology of these injuries, combined with Turnbull's

hypothesis that vascular compression and distortion due to antero-posterior flattening of the cord plays a major role in the pathophysiology of cord injury, suggest several potential opportunities for treatment.(18,26-28) The compression of the cord and the distortion and compression of its blood supply might be relieved by surgical decompression. Ischemia of the cord, either due to the primary injury or secondary events might be improved with augmentation of spinal cord perfusion. While Turnbull did not offer specific strategies, he did offer anatomical and pathophysiological rationale for the potential of maintenance of spinal cord perfusion pressures and cervical cord decompression for patients who sustain an acute central cervical cord injury, particularly those with pre-existing cervical spondylosis.(26-28) Maintenance or increases in systemic blood pressure may improve perfusion to the injured, distorted spinal cord.(1,3,10,11,22,23,29) Several contemporary series of spinal cord injured patients treated with aggressive medical management with maintenance of mean arterial blood pressure to high normal ranges (85 mm Hg to 90 mm Hg) have suggested improved neurological outcomes with this management plan.(10,11,24,29-31) Decompression of the cord has the potential to eliminate both cord compression and vascular compression and distortion.(3,5-8,30) Either or both of these treatment strategies may improve spinal cord blood flow in the acute central cervical spinal cord injury setting, which could translate into preservation of neurological tissue and recovery of neurological function. The benefit may or may not be realized at the site of primary injury, but rather at vulnerable adjacent spinal cord levels fed by sulcal and collateral arteries that pass through the injury site but supply the cord rostral and caudal to the site of injury. (1,22,23,26,28).

SUMMARY

The ideal management strategy for patients with acute central cervical spinal cord injuries appears to be multifaceted. As Schneider insisted years ago, a rapid, accurate diagnosis is essential. A detailed clinical examination, cervical spinal radiographs to assess vertebral column injury (see Radiographic Clearance in Symptomatic Patient recommendations) and MR assessment of the cervical spinal cord for intrinsic injury and/or compression will accomplish this goal. Many of these patients may require management in the ICU setting (see ICU Monitored Setting recommendations) for monitoring and treatment of cardiac, pulmonary and blood pressure disturbances. Blood pressure augmentation to MAP levels of 85 mm Hg to 90 mm Hg may be of benefit (see Blood Pressure Management recommendations). Early reduction of fracture or fracture dislocation injuries should be accomplished (see Subaxial Cervical Spinal Injuries recommendations). Administration of pharmacological agents may be of benefit according to specific parameters (see Pharmacological Therapy recommendations). Surgical decompression of the compressed spinal cord, particularly if the compression is focal, anterior and is approached anteriorly, appears to be of benefit in selected patients.

KEY ISSUES FOR FUTURE INVESTIGATION:

A prospective, controlled, randomized investigation of patients with acute central cervical spinal cord injuries treated with aggressive medical therapy alone (ICU management, blood pressure augmentation, closed fracture dislocation reduction), compared to those managed with aggressive medical therapy and early surgical decompression of the spinal cord is needed.

EVIDENTIARY TABLES:

First Author Reference	Description of Study	Data Class	Conclusions
Dai L and Lianshun J, 2000, *Spine*	Retrospective review of 24 patients with acute disc herniation as cause of ACCSCI treated with ACDF	Class III	Disc herniation common cause. Surgery successful in all patients, more rapid improvement. Poor outcome with fracture dislocation injuries.
Newey ML et al, 2000, *J Bone and Joint Surg (Br)*	Retrospective review of 32 patients with ACCSCI managed conservatively.	Class III	Improvement seen in most patients over time. Older patients had worse outcome.
Chen TY et al, 1998, *Spine*	Retrospective review of 37 patients with ACSI with pre-existing spondylosis. Many with central cord injury pattern. MR assessment of compression, cord injury. 16 managed with surgical decompression, 21 medically.	Class III	MR modality of choice to image cord compression/injury. Surgical decompression associated with more rapid improvement, shorter hospital and rehab.stay. No difference in outcome at two year follow-up.
Chen TY et al, 1997, *Surg Neurol*	Retrospective review of 114 patients with acute or chronic CCSCI. 28 patients managed with surgery (3 chronic patients), 86 medically. No randomization.	Class III	Surgery associated with more rapid and complete recovery, particularly in upper extremities, compared to similar patients managed medically. Patients with long segment stenosis had poor prognosis.
Bridle MJ, et al, 1990, *Paraplegia*	Random late assessment of 18 patients with ACCSCI.	Class III	Most patients improve over time, although most with long-term deficits, pain and dysfunction.
Roth EJ et al, 1990, *Arch Phys Med Rehabil*	Retrospective review of 81 rehab patients after ACCSCI.	Class III	Two age groups of patients, marked heterogeneity. In general most patients will improve over time. Outcome related to age, severity of initial injury.
Merriam WF et al, 1986, *J Bone and Joint Surg (Br)*	Retrospective review of 77 patients with ACCSCI. No patient with surgical decompression, 30 underwent late stabilization and fusion.	Class III	Marked variation among patients and injury patterns. Most improve. Outcome related to age, severity of initial injury.

First Author Reference	Description of Study	Data Class	Conclusions
Bose B et al, 1984, N*eurosurg*	Retrospective review of 28 patients with ACCSCI, 14 managed with aggressive medical therapy, 14 with medical therapy and surgical treatment. No randomization. Follow-up at time of discharge.	Class III	No patient worse with treatment, medical or surgical. Surgery provided more rapid, more complete recovery at time of discharge.
Brodkey JS et al, 1980, *Surg Neurol*	Retrospective review of seven patients with ACCSCI operated upon late after injury. All had stable, profound deficits and myelographic evidence of cord compression.	Class III	All had accelerated neurological improvement after surgery. Three normal at late follow-up. Surgery of benefit in select patients with persistent deficits and evidence of cord compression.
Shrosbree RD, 1977, *Paraplegia*	Retrospective review with late follow-up of 99 patients with ACCSCI managed conservatively.	Class III	Two groups identified. Younger patients with flexion rotation injuries. Older patients with hyperextension injuries. Outcome related to severity of initial injury.
Bosch A et al, 1971, *JAMA*	Retrospective review and long-term follow-up of 42 patients with ACCSCI managed conservatively.	Class III	Most patients improve over time. 75% will regain ambulatory skills, 56% regain functional hands. ten of 42 patients had late deterioration after initial gains ("chronic central cord syndrome").
Schneider RC et al, 1958, *J Neurol Neurosurg Psychiat*	Retrospective review of 12 additional patients with ACCSCI. Eleven managed expectantly, one managed with surgical decompression 13 hours after injury.	Class III	Two age groups of patients. Young patients with fracture dislocation injuries. Older patients with hyperextension injuries often without bony vertebral damage. Most patients improve. Expectant management is ideal treatment.
Schneider et al, 1954, *J Neurosurg*	Retrospective review (and first description) of eight patients with ACCSCI they managed (6 expectantly, two surgically) and discussion of six cases from literature.	Class III	Most patients with acute central cervical spinal cord injuries will improve with time and expectant management. Injury and its recovery follows specific pattern. Surgery contraindicated for this injury.

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