Management of Acute Traumatic Central Cord Syndrome (ATCCS)

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RECOMMENDATIONS

Level III

- Intensive care unit management of patients with acute traumatic central cord syndrome (ATCCS), 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 to 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

First introduced by Thorburn in 1887 and popularized by Schneider and Taylor, the concept of ATCCS has changed significantly during the past several decades.[1-7] In its severe form, as it was proposed by Schneider,[3] there is differential weakness of the upper and lower extremities and variable involvement of the sensory system and a variable impact on bladder function. In its most mild form it may result in symptoms only, including "burning hands," as reported by Maroon et al,[8] while the subject's neurological examination remains completely intact. Recent studies indicate that in order to apply the diagnosis of ATCCS, the upper extremity American Spinal Injury Association (ASIA) motor score should be at least 10 points less than the lower extremities ASIA Motor Score.[9,10] Based on 2 postmortem studies and considering the clinical thoughts of Foerster,[3] Schneider[11] proposed central necrosis with hematomyelia involving the centrally located laminations of the corticospinal tract as the main pathological feature of ATCCS. Recent necropsy studies by Levi et al,[12] Quencer et al[13] and Jimenez et al[14] have confirmed that hematomyelia does not necessarily have to be present. To the contrary, the major share of the pathology in ATCCS is swelling and disruption of the axons in the posterolateral funiculus of the spinal cord with very little evidence of bleeding. Tracing studies of Pappas et al,[15] anatomic transections of the corticospinal tract by Bucy et al,[16] and Marchi degeneration studies of Coxe and Landau[17] and Barnard and Woosley[18] all indicate that the somatotopic segregation of the corticospinal tract is valid in the internal capsule up to the cerebral peduncles. However, beyond those structures and at the level of the pyramids and the lateral funiculus of the spinal cord, there is no lamination of the descending fibers; therefore, no somatotopic organization. A current proposal by Levi et al[12] is that in primates, the corticospinal tract is critical for hand function but not locomotion.

Pathologically, ATCCS is a heterogeneous phenomenon.[19-21] Besides the classic hyperextension injuries superimposed on spinal stenosis, up to 60% of patients with ATCCS suffer from fracture subluxations, acute disc herniation, or, rarely, spinal cord injury without any radiographic abnormality.[19,20,22-37] In Schneider's[2,3,5] early series of 21 patients with ATCCS, there were 10 patients with cervical fracture injuries and

ABBREVIATIONS: ASIA, American Spinal Injury Association; **ATCCS**, acute traumatic central cord syndrome

11 patients with spinal stenosis without bony fracture injury. One of the fundamental characteristics of ATCCS is its potential for spontaneous recovery of function irrespective of the treatment provided. Surgical decompression for ATCCS has been advocated.[3,22,24,32] Only 2 of the 21 patients in Schneider's series were treated with surgical decompression, and in contemporary practice, early decompression of the injured spinal cord in the setting of spinal stenosis without bony fracture remains controversial.[2,3,5,19,22,24,31,32,34,37-41] In recent years, investigators have developed a better understanding of the pathophysiology of the secondary injury of spinal cord injury, emergency medical services and transport techniques have improved, imaging modalities and their availability and application have become first-rate, and the critical care management of acute spinal cord injury patients has evolved.[42-44]

In 2002, the guidelines author group of the Joint Section on Disorders of the Spine and Peripheral Nerves of the American Association of Neurological Surgeons (AANS) and the Congress of Neurological Surgeons (CNS) published a medical evidence-based Guideline on this important topic.[45] This present effort is to update the medical evidence on ATCCS focused on the specific issues of the natural history, medical management, and the potential surgical treatment of acute traumatic cervical central cord syndrome.

SEARCH CRITERIA

A computerized search of the National Library of Medicine (PubMed) database of the literature published from 1966 to 2011 was undertaken. The medical subject headings "central cord syndrome" yielded 1533 citations, "spinal cord injury combined with central cord syndrome" yielded 421 citations, and "traumatic central cord syndrome" yielded 74 citations. Non-English language citations were excluded.

These search parameters resulted in 29 articles specifically describing the management and outcome of patients with central cervical spinal cord injuries. The reference lists of these articles were searched for any additional articles germane to this topic. These 29 manuscripts make up the foundation for this updated review and are summarized in Evidentiary Table format. A comprehensive, contemporary bibliography is provided containing 101 citations.

SCIENTIFIC FOUNDATION

Diagnosis

Definition

ATCCS is an incomplete spinal cord injury in which the upper extremities are weaker, (at least 10 points in ASIA Motor Score) than the lower extremities with variable involvement of the sensory system and a variable effect on bladder function.[2,3,5]

Biomechanics

The basic biomechanics of ATCCS result from translation of kinetic energy into major injury vectors that damage anterior and posterior spinal cord columns centrally in the spinal cord with or without disruption of the bony vertebrae, the disc space, or spinal ligaments.[46-51]

Pathogenesis and Pathology

Regardless of the trajectory of the major injury vectors and moments, in nearly 70% of patients suffering from incomplete spinal cord injuries, the resulting deformation, stretch, and compression of the spinal cord will manifest as the clinical picture of central cord syndrome.[24,51,52] A major proportion of the reported case series describing the management of patients with ATCCS, including those of Schneider et al, describe a heterogeneous group of patients suffering from herniated discs, fractures and/or subluxations, or spinal stenosis without bony fracture.[2,3,5,20,21,23,27-29,53] Only a minority of the patients have been reported to have ATCCS due to hyperextension injuries without spinal stenosis or any other cervical spinal structural injury, bony or ligamentous.[19,29,37]

In the Chen et al[27] series, 16 of the 28 surgical cases (57%) of ATCCS they treated had either disc herniation or fracture subluxations, and 12 suffered from spinal stenosis without bony fracture. On the other hand, in the Dvorak et al[28] report, 45 of 70 subjects sustained disc herniations or fracture subluxations (65%). The remaining 25 patients had spinal stenosis without bony fracture. Nearly 50% (26 of 50) of the reported cases with ATCCS in the Guest et al[29] series had either acute disc herniation or fracture dislocations. Twenty-four patients had spinal stenosis without bony injury. In a recent report by Aarabi et al[19], describing 211 patients with ATCCS, 41 had herniated cervical discs (19.4%), 65 had fracture subluxations (30.8%), and 79 suffered from spinal stenosis without bony fracture (37.4%). In their review, 26 patients (12.3%) did not show any evidence of bony or ligamentous injury or spinal canal narrowing, although there was signal change on T2 weighted MR images of the spinal cord in these patients.

Kato et al[54] identified 127 trauma patients with cervical spinal cord injuries without bony injury on plain films or computed tomography. The incidence of ATCCS without bony injury was 32.2%. High-energy mechanisms of injury were significantly more common for younger patients. Older patients had a high incidence of injury sustained from a fall. Degenerative changes in the cervical spine and spinal stenosis were identified as risk factors for developing ATCCS without bony injury. The authors noted that ATCCS can occur in young adults during high energy injuries in the absence of pre-existing spinal disease.

In the original necropsy descriptions of Schneider et al,[2,3,5] in 5 patients with ATCCS and spinal stenosis who died between four and 38 days following trauma, the dominant pathological finding was central necrosis of the spinal cord in association with degeneration of neurons and white matter fibers. Swelling, disruption, and necrosis of the axons in the posterolateral funiculus

of the spinal cord correlate with magnetic resonance imaging (MRI) studies of patients with ATCCS.[12-14,55] MRI evidence of spinal cord injury following ATCCS has not been reported extensively.[19,27,34,40] In a recent study by Miranda[40] describing 15 patients with ATCCS, 12 of 13 patients had MR studies depicting edema only. A single patient had MR findings consistent with hemorrhage. In the Aarabi et al[19] investigation of 42 patients with ATCCS due to spinal stenosis without bony fracture, only one patient had evidence of hematomyelia on pre-operative MRI studies.

Imaging Criteria

ATCCS is a clinical entity and does not indicate the exact morphology of injury, the potential disruption of the disc or ligaments, the presence of bony injury, maximum spinal canal compromise, maximum spinal cord compression, and the degree of spinal cord injury.[19,27,37,40,53,56-58] These associated features and confounding contributing variables have direct impact on the management of patients with ATCCS. They define the degree of instability,[59,60] biomechanical failure,[46-49,60,61] the urgency of spinal cord decompression,[25,31,38,62] and the need for internal fixation of a potentially unstable cervical spine.[19,63] These spinal structural/anatomic features of ATCCS are best defined by reformatted computed tomography and MRI of the cervical spine as early as possible after injury.[64-78]

Clinical Criteria

Though declared as an independent clinical spinal cord injury entity in which the upper extremities are weaker than the lower extremities, the differential weakness of the upper and lower extremities in ATCCS was not defined until recently. A systematic review of the medical literature by Pouw et al[9,10] indicated that, in order for a patient to be eligible for the diagnosis of ATCCS, the ASIA Motor Score in the upper extremities should be 10 points less than the ASIA motor score in the lower extremities. In the study by Aarabi et al,[19] of 42 patients with ATCCS due to spinal stenosis without bony injury, the mean upper extremity ASIA motor score was 25.8 and the mean lower extremity ASIA motor score was 39.8.

Treatment

The level of medical evidence on the treatment of patients with ATCCS is Class III derived from case reports and case series. The strength of recommendations for a specific treatment strategy, or a combination of treatment strategies, aimed at preventing further spinal cord injury, protecting the spinal cord against secondary injury after ATCCS, and providing decompression of the spinal cord with or without spinal stabilization and fusion is therefore Level III.[2,5,19,22,23,26,28,29,31,34,37,62]

Schneider et al[2,5] recommended conservative management of patients with ATTCS for maximal potential recovery. Between 1954 and 1958, Schneider et al described 26 cases of spinal cord injury with the clinical picture of ATCCS. Six of the 26 cases were from the literature.[1,79,80] Two of 26 had a clinical picture indicative of motor complete spinal cord injury. Nine of 24 patients had unequivocal fractures or fracture subluxations on plain x-rays of the cervical spine, leaving only 15 patients with ATCCS due to spinal stenosis without bony fracture. Only three of 15 patients were imaged with cervical myelography. Three patients were treated surgically, two via laminectomy with sectioning of the dentate ligament followed by attempted transdural decompression of the ventral cord. Postoperatively, one patient was rendered quadraplegic, the other patient was unchanged neurologically. The third patient with a unilateral facet dislocation improved dramatically following operative reduction, decompression, and fusion. Thirteen of 15 patients who were treated expectantly with immobilization and physical rehabilitation demonstrated improved motor function; however, the majority of patients had persistent, significant, and enduring weakness/dysfunction of the distal upper extremities and hands. Recovery of function typically started in the lower extremities, was followed by bladder function return and finally upper extremity recovery, if it were to occur. They concluded that medical management resulted in a variable recovery in most patients with ATCCS, and that surgery that could harm patients was contraindicated in the setting of ATCCS.[2,3,5]

In contrast to Schneider et al's early recommendations about the role of surgery for ATCCS, other authors have described positive experiences with surgery in selected patients with ATCCS. In 1980, Brodkey et al[25] reported their experience with delayed decompression of the spinal cord in seven patients with ATCCS, all of whom had significant neurological deficits. All patients were imaged with myelography documenting compression of the spinal cord. Anterior cervical discectomy and fusion \ was performed in five patients, dorsal decompression in one and a combined anterior cervical discectomy and fusion and dorsal decompression in the seventh patient. Decompression of the spinal cord in these patients was performed from 18 to 45 days following trauma, at which time medical management was complete and the patients' neurological recovery and deficits had stabilized. All patients demonstrated accelerated neurological recovery after their surgical procedures.

In 1984, in a retrospective review, Bose et al[23] compared the ASIA motor score recovery at discharge of two groups of patients with ATCCS (14 in each group). One group was treated medically; most patients in this group had cervical spinal stenosis without bony fracture. The second group was treated medically but also underwent surgical decompression of the spinal cord followed by internal fixation and fusion; most patients in this group had cervical fracture/subluxation injuries. Surgery was performed 20 $\pm$ 4 days after admission. Although the two groups were not truly similar, the authors found that the group treated surgically did significantly better than those treated medically based on discharge ASIA motor scores ($P < 0.05$).

In 1997, Chen et al[27] reported their retrospective study of 114 patients with ATCCS who were either managed medically (86 patients) or medically with surgery (28 patients). Criteria

for surgical intervention were either spinal instability or lack of progress in neurological improvement (or neurological deterioration) in the setting of imaging evidence of spinal cord compression. Decompression was performed a mean of 10 days after admission. Twelve of 28 patients in the surgical group had spinal stenosis without bony fracture. The rest (16 patients) had either disc herniation or fracture dislocations as the cause of ATCCS. Their follow-up (mean 3.5 months) indicated that younger patients did better than older patients and that surgery was associated with a more rapid and complete return of neurological function, especially in the upper extremities, compared to nonoperative management.

In 1998, Chen et al[81] published another retrospective review of 37 patients with ATCCS due to spinal stenosis without bony fracture who had spinal cord compression. Twenty-one patients were managed nonoperatively. Sixteen patients were treated surgically for focal cord compression identified on MRI. Surgery was performed a mean of nine days after admission. In their study, improvement in recovery of function after surgery was more immediate and impressive in patients in the surgical group (81%) than was recovery in the medical group (62%). However, functional recovery in the two groups was nearly equal at late follow-up (two years).

In 2000, Dai and Jia[62] reported their retrospective investigation of the efficacy of surgical decompression of the spinal cord in a discrete group of patients with ATCCS due to focal cord compression/injury as determined by initial MRI. The researchers compared preoperative and postoperative ASIA motor scores in 24 patients with acute traumatic disc herniation (in seven patients, there was also a fracture dislocation). Although the overall motor recovery among the operated patients was impressive (average ASIA motor scores increased from 47.8 to 86.5), outcome was blunted in older patients and those with fracture dislocation injuries ($P < 0.01$). The degree of spinal cord compression was unrelated to the response to decompression ($P < 0.01$).

In a 2002 report by Guest et al, [29] the timing of decompression of the spinal cord and its efficacy on motor recovery was reported in 50 patients with ATCCS. Their cohort consisted of 24 patients with spinal stenosis without bony fracture, and 26 patients with disc herniation (16 patients) or fracture subluxations (10 patients). MRI of the cervical spine indicated evidence of contusion in 34 and no evidence of contusion in 16. Among the 24 patients with spinal stenosis without bony fracture, six underwent decompression within 24 hours of injury and 18 were decompressed after 24 hours. Ten of 26 patients with disc herniations or fracture dislocation injuries were treated early; 16 were treated late. The researchers evaluated the influence of early vs late decompression with the Post Spinal Injury Motor Function Scale. The timing of decompression did not affect the motor recovery in patients with spinal stenosis without bony fracture ($P = .51$). Older patients ($P = .03$) and those with early bladder dysfunction did poorly ($P = .02$). The response to early surgery was significantly better in patients with disc herniations or fracture dislocations as the cause of ATCCS ($P = .04$).

In 2005, Yamazaki et al[37] evaluated predictors of outcome in 47 patients with ATCCS due to spinal stenosis without bony fracture. Twenty-three patients were treated surgically and 24 were managed nonoperatively. Outcome was evaluated with the Japanese Orthopedic Association functional scale. Among 7 predictors, only sagittal diameter of the spinal canal and the time interval between injury and surgery influenced outcome. Patients with smaller sagittal diameters ($P = .04$) and those treated with surgical decompression later than two weeks after injury ($P < .001$) did significantly worse. The authors concluded that nonoperative management was inferior to surgery.

In a retrospective study reported in 2009, Chen et al[26] explored predictors of motor and functional outcome in 49 patients with ATCCS who had surgical decompression of the spinal cord. The pathology in this series was heterogeneous: spinal stenosis without bony fracture in 27 patients, disc herniation in 13, fractures in 8, and vertebral dislocation in 1 patient. Patients were followed for more than six months. The authors reported mean ASIA motor score improvement from 54.9 at admission to 89.6 at last follow-up ($P > .05$). Younger age at admission was a predictor of better outcome ($r = 0.55$, $P = .023$). Surgical decompression (less than 4 days from injury vs greater than 4 days) and the surgical approach utilized were not significant with respect to motor recovery or functional outcome. The Walking Index score (WISCI) was significantly lower among older patients. Almost one-third of the 49 patients expressed dissatisfaction with their outcomes when evaluated by the 36-Item Short Form Health Survey.

A 2010 systematic review[31] combined with a retrospective analysis of the Spine Trauma Study Group observational database addressed the question: "Is there a role for urgent (within 24 hours from injury to surgery) surgical decompression in acute central cord syndrome due to spinal stenosis without bony fracture to enhance neurologic recovery?" A total of 73 ATCCS patients had either early (n = =17) or late (n = =56) decompression of the spinal cord. Data analysis was controlled for age, gender, mechanism of injury, and comorbidities. At 12-month follow up, surgery within 24 hours of injury resulted in a 6.31-point greater improvement in total ASIA motor scores ($P = =.0358$), a higher chance of improvement in ASIA Grade (odds ratio of 2.81), and a 7.79-point greater improvement in the Functional Independence Measure (FIM) total score ($P = .0474$), compared to patients operated upon after 24 hours following injury.

In a retrospective study of 126 patients with ATCCS in 2010, Stevens et al[35] analyzed the response of the timing of surgical decompression at three separate time intervals: (1) Early—decompression within 24 hours of injury (16 patients), (2) Late—decompression after 24 hours and during the same hospital stay (34 patients; mean time to surgery 6.4 days), and (3) Delayed—decompression during a second hospital admission (17 patients; mean time interval of 137 days after trauma). Neurological outcome was assessed using the Frankel grading system. Comparing the Frankel outcome score of 67 patients treated with surgical decompression to 59 similar patients managed nonoperatively, the

investigators concluded that surgical decompression was safe, but that the timing of surgery did not affect outcome. Surgically treated patients fared better with respect to outcome, length of stay, and the incidence of complications compared to patients who were not treated surgically.

In 2011, predictors of outcome were evaluated by Aarabi et al[19] in 42 patients with ATCCS due to spinal stenosis without bony fracture (although 15 patients also had disc or ligamentous injuries on MRI). All patients were operated on and followed for at least 1 year. Outcome was evaluated using the ASIA motor score, FIM, manual dexterity tests, and an assessment of neuropathic pain, the Visual Analog Scale. The ASIA motor score at admission, midsagittal diameter of the spine, maximum spinal cord compression (MSCC) on MRI, maximum canal compromise (MCC) on MRI, length of signal change on T2 weighted MRI, number of skeletal segments involved in stenosis, timing of decompression (within 48 hours or after 48 hours), age, and surgical approach were considered factors that could influence outcome. Different domains of outcome were determined by different variables. At the time of admission, the average ASIA motor score was 63.8 (upper extremities score, 25.8 and lower extremities score, 39.8). The ASIA motor score at one year follow up (94.1) was significantly correlated to the admission ASIA motor score (P = .003), the midsagittal diameter (P = .02) and MCC (P = .02). FIM at 1 year follow up (111.1) was significantly influenced by the admission ASIA motor score (P = .03), MCC (P = .02), and age (P = .02). Manual dexterity at one year follow up (64.4%) significantly correlated with the admission ASIA motor score (P = .0002) and the length of the lesion on MRI (P = .002). Neuropathic pain (3.5) had a significant relationship with patient age (P = .02) and the length of the lesion on MRI (P = .04). The surgical approach (front, back, circumferential), the number of skeletal segments in which there was spinal stenosis, and the timing of decompression were not determinants of outcome.

Several postacute care outcome studies have described motor recovery and functional outcome in patients with ATCCS.[22,24,28,33,40,41,82-85] In 1971, without elaborating on the exact pathology, imaging studies and treatment, Bosch et al[86] reported on the long-term ambulation, hand function and sphincter control of 42 patients with ATCCS. As indicated in Table 1, there was a universal trend towards improvement of ambulation, manual dexterity, and sphincter control following acute hospitalization and in-patient rehabilitation for ATCCS. The authors observed that there was a paradoxical loss of neurological function, primarily ambulation skills and pyramidal tract involvement, at late follow up in 24% of patients who initially demonstrated neurological improvement after ATCCS ("chronic central cord syndrome").

In 1977, Shrosbree[87] reported on the functional outcome of a group of 90 heterogeneous patients with ATCCS who were treated conservatively. The initial severity of the patient's motor deficits dictated long-term outcome, including walking ability. Only 22% of patients with severe motor deficits upon admission became independent walkers; all had residual deficits in the hands. Two distinct groups of patients were recognized in this study: Younger patients (<50 years of age) who typically suffered from fracture subluxation injuries, and older patients who experienced ATCCS associated with spinal stenosis without bony injury.

In a 1990 retrospective investigation, Penrod et al[84] studied the effect of age on ambulation and activities of daily living in 51 patients with ATCCS. Ambulation at follow up was noted in 29 of 30 patients <50 years of age (97%), compared to seven of seventeen ATCCS patients older than 50 years (41%) (P < .002). Younger patients showed significantly more independence in activities of daily living and sphincter control. In a similar study also published in 1990, Roth et al[78] identified a better prospect for recovery in younger ATCCS patients. They compared Modified Barthel Index scores upon admission to rehabilitation and those obtained at discharge.

Tow and Kong[85] in 1998 retrospectively studied the long-term motor recovery and the functional outcomes of 73 patients with ATCCS. In their study, younger patients, those without spasticity, and those with a higher initial Modified Barthel Index had better functional outcome scores at late follow up.

In 2005, Dvorak et al[28] studied ASIA motor scores and FIM in a cohort of 72 patients whose clinical data were collected in a prospective manner. Forty-five of 72 patients suffered either a disc herniation (2 patients) or a fracture subluxation injury (43 patients). Twenty-five patients suffered from spinal stenosis without bony fracture. The investigators did not elaborate on the surgical management of their cohort; however, 41 patients were treated with surgery. Mean ASIA motor scores at follow up (92.3) correlated with mean ASIA motor scores at admission (58.7, P = .0001), formal education (P = .0001), and the absence of spasticity (P = .0001) at follow up. Patient FIM was positively correlated with higher ASIA motor scores at admission (P = .0009), formal education (P = .02), the absence of comorbidities (P = .04), the absence of spasticity, and younger age (P = .007). Independent ambulation was reported in 86% of patients at late follow up. Patient reported outcome (SF-36) improved in those with more formal education (P = .0000), fewer comorbidities (P = .009), the absence of spasticity (P = .03), and anterior column fractures as a cause of ATCCS (P = .03).

Aito et al[22] in 2007 offered a retrospective review of 82 patients with ATCCS. They did not find surgery to be a significant predictor of neurological outcome (ASIA Impairment Scale) or

TABLE 1. Function Attained Following Central Cord Lesion[86]

	Admission %	Discharge %	Follow up %
Ambulation	33.3	77	59[a]
Hand Function	26	42	56
Bladder Function	17	. . .	53
Bowel Function	9.5	. . .	53

[a]24% with late longtract deterioration: "chronic central cord syndrome."

TABLE 2. Evidentiary Table: Management of ATCCS

Citation	Description of Study	Evidence Class	Conclusions
Aarabi,[19] *J Neurosurg Spine*, 2011	Retrospective study of prospectively collected data on 42 patients with ATCCS for spinal stenosis who were operated on and followed for one year. The relationship of follow-up AMS, FIM, manual dexterity, and dysesthetic pain were correlated with admission AMS, age, maximum canal compromise (MCC), maximum spinal cord compression (MSCC), length of signal change on MRI, time past injury and surgery, sagittal diameter of spinal canal, number of stenotic motion segments, surgery, and mechanism of injury.	III	The AMS was significantly correlated to the admission ASIA motor score ($P = 0.003$), the midsagittal diameter ($P = 0.02$) and MCC ($P = 0.02$). FIM at one year follow-up (111.1) was significantly influenced by the admission ASIA motor score ($P = 0.03$), MCC ($P = 0.02$), and age ($P = 0.02$). Manual dexterity at one year follow up (64.4%) significantly correlated with the admission ASIA motor score ($P = 0.0002$) and length of lesion on MR imaging ($P = 0.002$). Neuropathic pain (3.5) had a significant relationship with patient age ($P = 0.02$) and the length of the lesion on MR imaging ($P = 0.04$). Surgical approach, mechanism of injury age, and the timing of decompression within 48 hours and after 48 hours of injury were not significant players in this study.
Fehlings,[99] *Spine*, 2010	Survey of 971 spine surgeons in reference to the timing of surgical decompression in spinal cord injuries.	III	While up to 80% of the responders agreed with surgical decompression of the spinal cord within 24 hours, there was no consensus in surgical decompression in ATCCS due to spinal stenosis.
Hohl,[30] *Spine*, 2010	Retrospective study of 37 patients with ATCCS to determine predictive factors in motor FIM at 12 months.	III	ASIA Motor Score ($P < 0.013$) and signal change on MRI ($P < 0.007$) were predictors of motor FIM at 1 year.
Lenehan,[31] *Spine*, 2010	Ambispective review of Spine Trauma Study Group cohort of 73 patients comparing motor and functional recovery 6 and 12 months following spinal cord decompression following ATCCS associated with spinal stenosis.	III	At 6 months and 12 months follow up patients (n = 17) who were decompressed within 24 hours did much better in AMS, AIS, and total FIM score than those decompressed after 24 hours of injury (n = 56).
Stevens,[35] *Spine Journal*, 2010	Retrospective review of the timing of decompression in ATCCS (within 24 and after 24 hours).	III	Sixteen patients were decompressed within 24 hours and 34 patients received decompression after 24 hours. Timing of decompression did not affect outcome.
Chen,[26] *J Neurosurg Spine*, 2009	Retrospective review of 49 patients who had surgical decompression of spinal cord within 4 days and after 4 days in ATCCS.	III	The timing of surgical decompression did not affect motor or functional outcome (AMS, WISCI).
Lenehan,[82] *Eur Spine*, 2009	Retrospective review of 50 patients with ATCCS who were followed for a mean of 42.2 months.	III	Absolute and relative improvement were greatest in patients <50 years of age.
Miranda,[40] *J Neurosurg Sci*, 2008	Retrospective review of motor score improvement in 15 patients with ATCCS.	III	The length of spinal cord edema significantly correlated with initial motor score (T2-weighted hyperintensity in serial MR studies).
Aito,[22] *Spinal Cord*, 2007	Retrospective review of 82 patients with ATCCS who were treated surgically (45%) or conservatively (55%). These included 44 patients with spinal stenosis.	III	Patients older than 65 had less neuropathic pain. Surgical decompression did not affect outcome.
Dvorak,[28] *Spine*, 2005	Retrospective review of 70 patients with ATCCS. 25 patients had spinal stenosis, 43 fracture subluxations, and 2 herniated disc.	III	AMS at follow up related to AAMS, level of education, and spasticity. FIM at follow up related to AAMS, education, comorbidities, and spasticity.

(Continues)

TABLE 2. *Continued*

Citation	Description of Study	Evidence Class	Conclusions
Song,[53] *J Clin Neurosci*, 2005	Retrospective review of 22 patients with ATCCS who had surgery.	III	Surgical decompression improved neurological status and prevented delayed neurological deterioration.
Guest,[29] *J Neurosurg*, 2002	Retrospective review of motor recovery in 50 patients with ATCCS. The cohort included 24 patients with spinal stenosis, 16 herniated discs, and 10 fracture dislocations.	III	Early surgery (within 24 hours) enhanced recovery of motor recovery in fracture dislocations but did not have much effect on spinal stenosis due to disc osteophyte complex.
Dai,[62] *Spine*, 2000	Retrospective review of 24 patients with ATCCS due to disc herniation.	III	Increased age had a negative effect on functional outcome.
Tow,[85] *Spinal Cord*, 1998	Retrospective review of 73 patients with ATCCS who had a mean of 51 days of follow up.	III	Patients with better admission Modified Barthel Index, younger age and less spasticity had better functional outcome.
Newey,[32] *J Bone Joint Surg Br*, 2000	Retrospective review of 32 patients with ATCCS managed conservatively.	III	Improvement seen in most patients over time. Older patients had worse outcome.
Chen,[81] *Spine*, 1998	Retrospective review of 37 patients with ACSI with preexisting spondylosis. Many with central cord injury pattern. MRI assessment of compression, cord injury. 16 managed with surgical decompression, 21 medically.	III	MRI modality of choice to image cord compression/injury. Surgical decompression associated with more rapid improvement, shorter hospital and rehabilitation stay. No difference in outcome at 2year follow up.
Chen,[27] *Surg Neurol*, 1997	Retrospective review of 114 patients with ATCCS. This cohort consisted of 28 surgical and 86 medical patients.	III	Younger patients had better recovery.
Waters,[41] *Spinal Cord*, 1996	Prospective multicenter study of 19 patients with ATCCS due to spinal stenosis.	III	On the average natural rate of recovery was doubling of ASIA motor scores at one year of follow up.
Bridle,[24] *Paraplegia*, 1990	Retrospective evaluation of 18 patients with ATCCS for pain, hand dexterity, and occupational performance.	III	Significant difference was found between males and females on the MPIs.
Penrod,[84] *Arch Phys Med Rehab*, 1990	Retrospective review of ADL in 51 patients with ATCCS.	III	ADL, ambulation, and bladder function better in younger patients.
Roth,[33] *Arch Phys Med Rehab*, 1990	Retrospective evaluation of 81 patients with ATCCS including 63% fracture dislocations.	III	Younger patients had better rehabilitation outcome on Modified Barthel Index.
Merriam,[39] *J Trauma*, 1986	Retrospective review of 77 patients with ATCCS. No patients with surgical decompression, 30 underwent late stabilization and fusion.	III	Marked variation among patients and injury patterns. Most improved. Outcome related to age and severity of initial injury.
Bose,[23] *Neurosurgery*, 1984	Retrospective study of 28 patients with ATCCS including 19 patients with extension injury. 14 patients were treated conservatively and 14 had surgery.	III	Surgical intervention was safe at discharge; operated patients did better than the conservatively treated group.
Brodkey,[25] *Surg Neurol*, 1980	Seven patients with anterior cord compression were decompressed in a subacute fashion	III	All patients improved clinically very rapidly.
Shrosbree,[87] *Paraplegia*, 1977	Retrospective review with late follow up of 99 patients with ATCCS managed conservatively.	III	Two groups identified. Younger patients with flexion rotation injuries. Older patients with hyperextension injuries. Outcome related to age and severity of initial injury.
Bosch,[86] *JAMA*, 1971	Retrospective review and long-term follow-up of 42 patients with ATCCS managed conservatively.	III	Most patients improved over time; 75% regained ambulatory skills, 56% regained functional hands, and 10/42 patients had late deterioration after initial gains ("chronic central cord syndrome").

(Continues)

TABLE 2. *Continued*

Citation	Description of Study	Evidence Class	Conclusions
Schneider,[5] *J Neurol Neurosurg Psychiatry*, 1958	Retrospective review of 12 additional patients with ATCCS. Eleven managed expectantly, 1 managed with surgical decompression 13 hours after injury.	III	Two age groups of patients. Young patients with fracture dislocation injuries. Older patients with hyperextension injuries often without bony vertebral damage. Most patients improved. Expectant management is ideal treatment.
Schneider,[3] *J Neurosurg*, 1954	Review of 14 cases of ATCCS: 8 personal and 6 from the literature. This cohort was a mixed bag of discosteophyte complex and fracture dislocations.	III	It was recommended that surgery should not be performed in ATCCS.
Schneider,[2] *J Neurosurg*, 1951	Retrospective review of 2 patients with disc herniation and central cord syndrome.	III	Significant improvement in one of two patients following surgery.

functional outcome (FIM and WISCI). They described 38 patients with ATCCS who were treated with surgery, most often for a disc herniation or fracture subluxation injury. Forty-four patients were treated without surgical intervention. All patients in this latter group had ATCCS associated with spinal stenosis without bony injury. Lack of congruity of the two patient groups makes it impossible to draw meaningful conclusions about the effect of surgery on neurological and functional outcomes. Overall, younger ATCCS patients did better at 18 months follow up (mean). Patients older than 65 years of age reported less neuropathic pain.

Since the first publication of the "Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries," the management of ATCCS has remained controversial.[19,22,23,26-28,31,38,45,62,84] The heterogeneity of this group of patients makes any firm conclusion about the management of ATCCS virtually impossible.[19,21,22,26,28] Based on a current review of the literature, there seem to be four distinct groups of patients who manifest the clinical features of ATCCS. These groups are characterized by different biomechanics, pathology, and their response to surgical and medical treatment. Approximately 10% of patients with ATCCS have MRI evidence of signal change within the spinal cord with no other radiographic abnormality.[19] It is recommended that these patients be managed medically. Roughly 20% of patients present with an acute disc herniation as the cause of ATCCS.[26,27,62,86] Surgical intervention is recommended for this group. Nearly 30% of patients with ATCCS have cervical spine skeletal injuries in the form of fracture subluxation injuries.[22,23,27,28,81] In this group of patients, early re-alignment of the spinal column (closed or open) with spinal cord decompression is recommended. The last group of patients (approximately 40%) have spinal stenosis without evidence of bony or ligamentous injury.[2,5,19,21-23,26-28,37,53,82,88] It is in this group of patients that the management of ATCCS remains the most controversial.[2,5,19,22,23,26-28,31,37,42,43,73,76,78,81,85,88-93] The variable degree of spontaneous recovery of neurological function in patients with ATCCS due to spinal stenosis without bony injury compromises the study of surgical vs medical management strategies.[2,5,22,24,25,34,84] Data are summarized in Table 2.

SUMMARY

Class III medical evidence supports the aggressive medical management including ICU care of all patients with a spinal cord injury, including those with ATCCS. Class III medical evidence suggests that surgery for ATCCS is safe and appears to be efficacious (in conjunction with medical management) for patients with focal cord compression, or to provide operative reduction and internal fixation and fusion of cervical spinal fracture dislocation injuries. The role of surgery for patients with ATCCS with long segment cord compression/injury or with spinal stenosis without bony injury remains a subject of debate in the literature.[19,23,26,27,31,37,38,81,94-101] Patient age and comorbidities are important factors when considering surgical treatment for patients with ATCCS.[19,22,26,28-29,33,35,81,84,85]

KEY ISSUES FOR FUTURE INVESTIGATION

A prospective, controlled, randomized, or case control investigation of patients with ATCCS due to spinal stenosis without bony fracture treated with aggressive medical therapy alone (intensive care unit management, blood pressure augmentation, closed fracture dislocation reduction), compared to patients managed with aggressive medical therapy and early surgical decompression of the spinal cord would provide Class II medical evidence on this important topic.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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