Effectiveness of surgical treatment for traumatic central cord syndrome

Clinical article

Liang Chen, M.D., Ph.D., Huilin Yang, M.D., Ph.D., Tongqi Yang, M.D., Yaqozeng Xu, M.D., Ph.D., Zhaohua Bao, M.D., and Tiansi Tang, M.D.

Department of Orthopaedic Surgery, The First Affiliated Hospital of Suzhou University, Suzhou, People's Republic of China

Object. The authors undertook a study in patients with traumatic central cord syndrome (TCCS) who underwent surgical intervention. They retrospectively assessed the motor score improvement and functional status and identified prognostic predictors of improvement.

Methods. Between March 1999 and May 2004, 49 patients with TCCS were surgically treated. Motor scores were collected at admission and follow-up using the American Spinal Injury Association (ASIA) Impairment Scale. The 36-Item Short Form Health Survey (SF-36) was administered. Other parameters including walking index, spasticity, bladder management, and neuropathic pain scores were recorded. Patients were asked to assess their level of satisfaction with their final symptoms.

Results. The average ASIA score, converted into numeric values, was increased from 54.9 at admission to 81.9 and 89.6 at 6 months and final follow-up, respectively. Significant improvement of ASIA score was achieved within the first 6 months of surgery. No significant difference was found between patients who underwent surgery within 4 days of injury or after 4 days of injury, adopting different approaches (anterior, posterior, or a combination), or with different pathological entities (acute disc herniation, fracture or dislocation, or multilevel degeneration). The ASIA score improvement had a positive correlation with the age at injury ($r = 0.505$, $p = 0.023$). The SF-36 data at 6 months and final follow-up were not as satisfactory as the improvement in ASIA scores, and almost one-third of patients expressed dissatisfaction with their final symptoms. For patients who were older than 65 years at injury, the mean follow-up Walking Index for Spinal Cord Injury (WISCI) score was statistically lower than it was in younger patients. The presence of spasticity or neuropathic pain at follow-up was not related to age, sex, ASIA motor score, or WISCI outcome.

Conclusions. Surgical intervention can be safely applied in patients with TCCS. Significant improvement of ASIA score was achieved during the first 6-month period of follow-up. Factors including type of lesion, timing of surgery within or after 4 days of injury, and surgical approach were not significantly associated with final ASIA score. The improvement in the ASIA motor score was positively correlated with age at injury. No significant correlation was found between or among the presence of spasticity, neuropathic pain, and ASIA score at final visit. Almost one-third of patients were not satisfied with their final symptoms. (DOI: 10.3171/2008.9.SPI0822)

KEY WORDS • American Spinal Injury Association motor score • Short Form Health Survey • spasticity • surgical treatment • traumatic central cord syndrome • Walking Index for Spinal Cord Injury

TRAUMATIC central cord syndrome is characterized by disproportionately greater weakness of the upper extremities than the lower extremities, variable sensory loss, and bladder dysfunction. Since the publication of the article by Schneider et al., TCCS has been treated conservatively because most patients improved spontaneously and because the various surgical approaches used at that time would most likely damage the spinal cord further. However, the natural history of TCCS often proceeds with an initial improvement of neurological function followed first by a plateau in recovery and then by late deterioration. In 1971, Bosch et al. reported that only 60% of their conservatively treated patients re-
mained functional at long-term follow-up and that 25% of patients in whom enough function was recovered to enable ambulation later became wheelchair bound as a result of chronic myelopathy. Recently, several papers in the literature have suggested potential benefits of early surgical treatment in selected cases, leading to controversy and wide variations in management.\textsuperscript{5,11,16,26} Bose et al.\textsuperscript{3} retrospectively compared data obtained in 14 surgical and 14 nonsurgical patients and found that higher motor scores at discharge were recorded in the surgical group; however, the follow-up period was short and significant selection bias limited their conclusion. From the existing literature, it is difficult to make comparisons among these studies because of the variabilities in clinical manifestation, treatment options, and outcome measurements.

The purpose of this retrospective study was to assess the motor score improvement and functional status in 49 surgically treated patients with TCCS and to attempt to identify prognostic predictors of improvement in impairment and function.

**Methods**

Between March 1999 and May 2004, 56 consecutive patients with TCCS were admitted to our spinal unit, and surgical treatment was recommended. Inclusion criteria were a primary diagnosis of TCCS (defined as a cervical SCI producing disproportionately greater weakness in the upper limbs than the lower limbs, varying degrees of sensory loss, and bladder dysfunction). Surgical indications mainly included persistent compression of the spinal cord that correlated with the level of neurological deficit, or gross cervical instability. The final evaluation of neurological impairment and functional status was performed in 2006, at least 25 months (mean 56 months) after injury. Patients were excluded if the following occurred: 1) they had associated severe head, nerve, or extremity injuries; 2) they died before follow-up evaluation; 3) they could not be located; and 4) they had missing data. Overall, 7 patients were excluded based on the aforementioned criteria, and 49 patients were entered in our study.

The following data were collected for each patient: sex, age at injury, cause of injury, type of injury and treatment (anterior approach, posterior approach or combination), complications, admission, 6-month and final-visit motor status (based on the score on the ASIA Impairment Scale), SF-36 score,\textsuperscript{15} and 6-month and final-visit WISCI status.\textsuperscript{16} The presence of neuropathic pain and spasticity, as well as the type of bladder management, was recorded. Patients were asked to assess their level of satisfaction with their final symptoms on a scale of 1 to 5, where scores < 3 were considered “unsatisfactory.”

The causes of injury were divided into 4 groups: 1) road traffic accident; 2) fall from height; 3) sports injury; and 4) others. The types of injury were classified according to radiographs, CT scans, and MR images as the following: 1) acute disc herniation; 2) fracture and/or dislocation; and 3) multilevel degeneration without evidence of trauma. The treatment was classified as anterior approach, posterior approach, or combination. An anterior approach was used in patients with single-level disc herniation or significant anterior compression caused by vertebral body fracture, large osteophyte, or spondylotic stenosis < 3 vertebral levels; a posterior approach was recommended for patients with spinal stenosis at ≥ 3 levels, or compression caused by posterior elements; a combined anterior-posterior approach was selected for patients with spinal cord compression both from ventral and dorsal sides. The severity of neurological involvement was assessed using the ASIA Impairment Scale motor score. A patient's overall physical and mental status was measured using the SF-36 questionnaire, and a patient's ability to walk was measured using the WISCI scale (score range 0–20). The patient was considered to have spasticity if his Ashworth score\textsuperscript{12} was > 2 (range 0–5). Bladder management status was divided into 2 groups: 1) spontaneous voiding or 2) no spontaneous voiding, which included indwelling catheter, intermittent catheter, and reflex voiding.

A descriptive statistical analysis was performed for all quantitative and categorical variables. All ASIA and SF-36 data are expressed as the mean ± SD. A paired t-test was performed to compare the pre- and postoperative scores. Linear regression analysis was used to correlate improvement in ASIA score and age at injury. Statistical significance was defined as p < 0.05.

**Results**

**Demographic Characteristics**

The study population consisted of 40 men and 9 women whose mean age at the time of injury was 55.9 years (range 22–76 years). The causes of injury were road traffic accident in 29 cases, fall from heights in 16, sports injury in 3, and other in 1. Cervical disc herniation occurred in 11, fracture in 6, and pure dislocation in 1; in 31 patients we documented multilevel degeneration without evidence of acute disc herniation, fracture, or dislocation. Complications occurred in 9 patients and included misplacement of screw into the disc space at the time of fixation in 1, respiratory problems in 3, deep vein thrombosis in 1, and urinary tract infection in 4.

**Admission and Follow-Up ASIA and SF-36 Scores**

In the complete group of 49 patients, the mean ASIA motor score at admission was 54.9 ± 18.7, whereas the mean 6-month and final-visit ASIA scores were 81.9 ± 20.9 and 89.6 ± 21.7, respectively. Significant improvement in ASIA scores was achieved during the first 6 months after surgical intervention. Although ASIA motor scores at 6 months and the final visit were encouraging, SF-36 data were not as satisfactory as expected (Table 1). Many patients complained that spasticity and neuropathic pain were major factors leading to poor quality of life. On the basis of timing of surgery, surgical procedure, and potential pathology, patients were divided into subgroups; the average ASIA scores of each subgroup are shown in Table 2. No significant difference was found between patients who underwent surgery within 4 days of injury or after 4 days of injury, adopting different approaches (anterior, posterior, or anterior-posterior), or with different pathological entities (disc herniation, fracture or dis-
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The improvement in ASIA motor score had a positive correlation with the age at injury \( r = 0.505, p = 0.023 \); in younger patients the improvement in the ASIA motor score was greater than in older patients.

Walking Ability and Bladder Management

To analyze ambulatory status, patients were divided into 3 groups based on their WISCI scores: Group 1, patient cannot walk (WISCI score range 0–2); Group 2, patient can walk with different types of aid (score range 3–17); and Group 3, patient can walk independently (score range 18–20). The mean 6-month postoperative WISCI score was only 12, and the final score was 16. No significant difference was found among subgroups classified by type of injury, timing of surgery, and surgical approach. During the follow-up period, 3 patients > 65 years of age who could walk independently (Group 3) at 6 months gradually lost independence and needed some form of assistance (Group 2).

Admission and follow-up bladder management status is described in Table 3. At admission, spontaneous bladder emptying was not influenced by age, sex, or type of injury, but it was correlated with ASIA and WISCI scores. Spontaneous voiding was present in 80\% of patients with an ASIA score > 80, whereas only 50\% of patients with an ASIA score < 50 could empty the bladder spontaneously. The voiding was spontaneous in one-third of those whose WISCI score was between 3 and 17, and the rate increased to three-fourths in the group between 18 and 20. Nevertheless, the improvement in bladder function during the follow-up period was not influenced by age or sex, or by ASIA or WISCI score.

Spasticity, Neuropathic Pain, and Overall Level of Satisfaction

Comparisons were made between ASIA scores/spasticity and neuropathic pain. No significant difference was found in ASIA score and WISCI scores among patients with or without spasticity at admission, 6 months, and the final visit. Similarly, no significant difference was found in ASIA score and WISCI scores among patients with neuropathic pain and those without neuropathic pain, both at admission and at follow-up. Although the improvement of ASIA scores in 49 patients was impressive, 16 patients (32.7\%) expressed significant dissatisfaction with their symptom status (Fig. 1).

Table 1: Summary of admission and follow-up ASIA motor and SF-36 scores obtained in 49 surgically treated patients with TCCS

<table>
<thead>
<tr>
<th>Interval</th>
<th>Mean ASIA Score</th>
<th>Mean SF-36 Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PF</td>
<td>RP</td>
</tr>
<tr>
<td>admission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 mos</td>
<td>81.9</td>
<td>42 ± 14</td>
</tr>
<tr>
<td>final visit</td>
<td>89.6</td>
<td>57 ± 16</td>
</tr>
</tbody>
</table>

*BP = bodily pain; GH = general health; MH = mental health; PF = physical functioning; RE = role—emotional; RP = role—physical; SF = social functioning; VT = vitality.

Table 2: Summary of admission and follow-up ASIA motor score stratified by subgroup

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Patients</th>
<th>Admission</th>
<th>6 Mos</th>
<th>Final Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>timing of op</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>w/in 4 days</td>
<td>21</td>
<td>49.2 ± 18.1</td>
<td>82.4 ± 26.5</td>
<td>88.7 ± 24.4</td>
</tr>
<tr>
<td>after 4 days</td>
<td>28</td>
<td>59.1 ± 15.2</td>
<td>81.6 ± 22.7</td>
<td>90.3 ± 18.6</td>
</tr>
<tr>
<td>op approach</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>anterior</td>
<td>20</td>
<td>56.3 ± 19.1</td>
<td>79.7 ± 19.9</td>
<td>92.1 ± 23.4</td>
</tr>
<tr>
<td>posterior</td>
<td>20</td>
<td>53.2 ± 15.4</td>
<td>85.2 ± 17.5</td>
<td>86.0 ± 21.5</td>
</tr>
<tr>
<td>A-P</td>
<td>9</td>
<td>55.3 ± 16.2</td>
<td>79.6 ± 20.1</td>
<td>92.2 ± 19.7</td>
</tr>
<tr>
<td>lesion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>disc herniation</td>
<td>13</td>
<td>62.3 ± 19.3</td>
<td>81.3 ± 19.9</td>
<td>93.7 ± 21.7</td>
</tr>
<tr>
<td>fracture</td>
<td>8</td>
<td>54.1 ± 18.6</td>
<td>78.7 ± 21.3</td>
<td>90.1 ± 16.8</td>
</tr>
<tr>
<td>dislocation</td>
<td>1</td>
<td>67.0</td>
<td>83.0</td>
<td>87.0</td>
</tr>
<tr>
<td>degeneration</td>
<td>27</td>
<td>51.0 ± 16.1</td>
<td>83.2 ± 25.4</td>
<td>87.5 ± 19.7</td>
</tr>
</tbody>
</table>

* A-P = anterior-posterior.

when Bosch et al. 2 reported that many conservatively

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matically after surgery. The conservative strategy of Sch-

den et al. was widely accepted until the early 1970s. Originally Schneider et al. 23 postulated that the syndrome’s characteristic clinical manifestations resulted from the development of central hematomyelia within the spinal cord, with this process selectively injuring the medial fibers of the corticospinal tract, which were presumed to subserve arm and hand function. However, other authors challenged this theory. Using human autopsy material, Uribe et al. 25 showed that the classic anatomical description of central cord hematomyelia is not absolute, as pathological analysis revealed in most cases a diffuse, dorsal, lateral, white matter injury, and this information correlated well with ante- and postmortem MR imaging findings. Levi et al. 14 also stated that the main function of the corticospinal tract is to subserve fine motor movements to the distal musculature, especially the upper limbs. Any injury involving the corticospinal tract from the medulla to the cervical enlargement may result in TCCS. Recent neuropathological studies further suggested that the clinical deficits observed in the early phase of CCS are largely due to the loss of large, monosynaptic, rapidly conducting, myelinated corticospinal fibers. 13

Schneider et al. 23 suggested that CCS was associated with a fairly good prognosis, because as the spinal cord edema subsided, motor function would recover, following a definite pattern, and thus, surgical intervention was contraindicated. Furthermore, the condition of some of the patients treated with laminectomy deteriorated dramatically after surgery. The conservative strategy of Schneider et al. was widely accepted until the early 1970s when Bosch et al. 7 reported that many conservatively treated patients experienced late-onset neurological deterioration, and only 60% of them remained functional despite a period of initial improvement. Newey et al. 18 studied 32 patients with TCCS who were managed conservatively and found that after a mean of 8.6 years of follow-up, ASIA score–measured function at discharge was usually maintained, but patients who were > 70 years of age at injury did poorly. Recently, several authors have suggested potential benefits of early surgical intervention in selected cases, leading to controversy and wide variations in treatment. Duh et al. 9 have suggested that surgery provides 2 potential advantages over conservative treatment. First, improved neurological recovery achieved after early decompression of the cord and nerve roots may permit earlier rehabilitation; second, stable spinal fixation may prevent further SCI and subsequent neurological deterioration. Like Duh et al., we have traditionally managed acute TCCS based on patients’ neurological and radiological findings. We recommended surgery for patients with persistent spinal cord compression that correlates with the level of neurological deficit and for those with gross cervical instability. Bose et al. 3 compared motor function recovery in surgically and conservatively treated patients and reported that both groups exhibited significant motor recovery based on the ASIA scoring system; a greater degree of motor recovery was found in the operative group. However, because surgery was reserved for patients with mechanically unstable injury and those patients with less neurological recovery potential, significant patient selection bias limited their conclusion. In 2002, Guest et al. 11 reported that early surgery (within 24 hours of injury) is safe and cost-effective compared with late surgery in the treatment of TCCS, based on the length of the intensive care unit stay, the length of the hospital stay, and improved overall motor recovery, in patients whose CCS was related to acute disc herniation or fracture. In the present study we found that surgery within 4 days of injury produced no significant advantage over late surgery. Thus, the role and timing of surgical decompression and reconstruction are yet to be defined.

Several authors have identified an age-related difference in outcomes. 7,18,19,21,22 Newey et al. 18 reported that patients > 70 years of age did poorly. Roth et al. 22 and Penrod et al. 19 also found that age was an adverse prognostic factor in relation to functional outcome. It has been postulated that elderly patients tend to have a higher incidence of cervical spondylosis and cord ischemia from atherosclerotic changes of the vertebral and feeding ves-
sels, and this may result in poor neurological recovery. In addition, elderly patients tend to have a higher incidence of comorbidities. In the current study, by analyzing age at injury as a continuous variable, we found a positive correlation between age and ASIA score improvement; we also had 3 patients > 65 years of age at injury who could walk independently 6 months postoperatively and who gradually lost independence. Additionally, 1 patient with good bladder control lost the ability to void the bladder spontaneously.

In terms of the incidence of spasticity, Perkash\textsuperscript{20} found that 48% of patients suffered from severe spasticity 3–6 months after the injury. Aito et al.\textsuperscript{1} reported that 54% of patients suffered from spasticity and 72% of these patients rated spasticity as a problem in daily life. In 2005, Dvorak et al.\textsuperscript{10} indicated that spasticity was positively correlated with the final ASIA motor score and negatively correlated with functional status. In the current study, 24.3% of patients suffered from spasticity, two-thirds of whom needed antispasticity drugs (Fig. 2); however, ASIA motor score–based admission and follow-up neurological status did not differ significantly when compared with that in patients without spasticity. Contrary to the findings of Newey et al.\textsuperscript{18}, we determined that spasticity influenced functional outcome when results were measured using the SF-36 and WISCI instruments.

Fig. 2. Imaging studies obtained in a 33-year-old man injured in a traffic accident. A and B: Preoperative radiographs showing congenital fusion of C2–3. C: Sagittal MR image demonstrating C4–5 cord compression and an intramedullary high signal intensity. D and E: Radiographs obtained after anterior decompression, reconstruction, and posterior laminectomy. A significant ASIA score improvement was achieved, but the patient still suffered from severe spasticity postoperatively.
Our study is limited because of the relatively small number of patients and because the follow-up intervals ranged from 25 months to 7 years. Another limitation is the lack of a control group in which no surgery was performed, and thus, direct comparison between groups was not possible. We also recognized that our patient group was heterogeneous, and the cases involved different kinds of pathology. Despite these limitations, we suggest that surgical intervention can be safely applied for TCCS patients with persistent spinal cord compression and/or gross cervical instability. The overall improvement in ASIA scores was satisfactory. Careful examination of clinical and radiological findings may provide an important basis for selection of the appropriate treatment method.

Conclusions

Surgical intervention can be safely undertaken in patients with TCCS. Significant improvement in ASIA scores was achieved during the first 6 months after surgery. Factors including type of disease, timing of surgery, and surgical approach were not significantly associated with final ASIA motor score. A positive correlation was found between age at injury and ASIA score improvement. No significant correlation was found between the presence of spasticity, neuropathic pain, and ASIA score at the final visit. Almost one-third of patients were not satisfied with their final symptoms.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

References
