The neurological and skeletal outcome in patients with closed cervical spinal cord injury

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Sixty-one patients with closed cervical spinal cord injury were cared for within a defined protocol and followed for at least 1 year. Neurological recovery and healing of spinal structures were evaluated at intervals. Forty-three patients were managed without surgical intervention at the site of spine trauma, and the incidence of spontaneous fusion ("autofusion") was noted. Surgical fusion was performed on 17 patients, mainly to restore spinal stability and alignment. One patient underwent laminectomy without fusion. In both the surgical fusion and the autofusion groups, there were significant numbers of patients who improved neurologically, including some designated as having a complete spinal cord lesion at the initial neurological examination. As expected, better spinal alignment was achieved in the surgical group, although alignment in the nonsurgically treated group was generally acceptable. The majority of patients developed radiographically apparent callus formation anterior to the injured vertebral bodies, regardless of the mechanism of injury or the method of treatment. After 3 months all patients who underwent surgical fusion achieved spinal stability, as did the majority of patients in the autofusion group. Only individuals with flexion-distraction injuries who did not undergo surgical fusion appeared to be at risk for progressive spinal column deformity. Neither retropulsion of bone fragments nor angulation at the fracture site appeared to correlate with a poor neurological outcome, since improvement in neurological function occurred similarly in patients with and without these deformities.

KEY WORDS - spinal cord injury • cervical spine • spinal fusion

CONTROVERSY still surrounds the issues of operative versus nonoperative management following cervical spinal cord trauma. The controversy has not been resolved by a statistically valid study, in large part because of the difficulties in designing a multicenter project such as would be required to obtain the necessary number of patients. Many American and some European authors have treated these patients by surgical decompression of the injured spinal cord from either a posterior approach or an anterior approach. On the other hand, English, Australian, and many European investigators have generally favored a nonoperative approach, preferring to maintain the patient in tongs and traction for 6 weeks or more following their injury so as to allow spontaneous fusion ("autofusion") to occur.

On the basis of widely accepted results of comprehensive care for spinal cord-injured patients and our own accumulated experience, we have entered into a system of care for spinal cord injury in which common management protocols are shared among four institutions and among physicians within the system. This system has made it possible to trace the natural history of healing of the cervical spine and spinal cord, and to record any deviations from such natural history in patients undergoing operative fusion. The outcome in these patients was studied from the neurological and skeletal viewpoint only.

Clinical Material and Methods

All patients were treated within a defined system of care called "The Texas/South Central Spinal Cord Injury Care System." The system conformed to the standards of the Commission on Accreditation of Rehabilitation Facilities (CARF). The institutions involved in the care system included one spinal cord injury rehabilitation facility and three separate acute-care hospitals, each with a trauma center and a segregated area for spinal cord-injured patients. All patients in this series were followed and cared for within this system from the date of their injury until at least 1 year following injury. Some were initially treated in outlying hospitals and then transferred to one of the three co-
operating acute-care facilities within the system. One patient underwent a surgical procedure (laminectomy) prior to transfer.

Outcome factors evaluated at 3, 6, and 12 months following injury included: 1) the neurological level and completeness of the lesion, based on the criteria of Frankel, et al.;11 2) the mechanism of injury, modified from the technique of Allen, et al. (namely, flexion with distraction, flexion with compression, compression, and extension);1 3) the degree of spinal angulation; 4) the displacement of bone structures into the spinal canal (angulation and displacement were measured according to the methods described by Dickson, et al.); and 5) the presence or absence of spinal instability, defined as abnormal movement of the cervical spine at and around the area of injury.

Eighty patients with injury to the cervical spinal cord were admitted to our system of care during a 2-year period from July, 1981, through June, 1983. Nineteen of these patients were excluded from this study because they: 1) had penetrating rather than closed injuries (six patients); 2) suffered fractures of C-1 or C-2 only (three patients); 3) exhibited no bone injury (two patients); 4) had died (one patient); or 5) were lost to follow-up review (seven patients). Fifty-two male patients and nine female patients with a mean age of 30 years remained in the study; all of these patients were admitted into this system within 24 hours, except for the patient with the laminectomy who was admitted within 36 hours.

The etiology for the cervical trauma of the 61 remaining patients was as follows: automobile accident in 28 cases (46%); sports-related injury in 18 (30%); motorcycle accident in seven (11%); falls in six (10%); and other causes in two (3%). The lowest intact neurological segment was C-2 for two patients, C-3 for two, C-4 for 10, C-5 for 17, C-6 for 16, C-7 for 12, and C-8 for two. The distribution of bone damage was similar. Bone injuries were classified according to those vertebrae that showed the major degree of injury; two adjacent vertebrae were considered as a unit. The major vertebral injury was at the following spinal segments: C2–3 in three patients; C3–4 in six; C4–5 in 14; C5–6 in 19; C6–7 in 16; and C7–T1 in three.

Forty-three of the 61 patients were treated nonsurgically. Seventeen patients underwent surgical fusion for spinal stabilization: four by an anterior approach, and 13 by a posterior approach. The remaining patient was subjected to early laminectomy without fusion for decompression of the spinal cord before entering our care system; in this report, he is considered separately from the rest of the subjects. In all patients who underwent surgical fusion, with one exception, surgery was performed within 3 weeks of the date of injury. That one exception was initially scheduled for autolysis but was found to have gross spinal instability after 6 weeks. Three additional patients were initially managed nonsurgically but displayed late instability more than 3 months after injury and were offered cervical fusion.

Two accepted and achieved good restoration of spinal alignment and stability. The third, a quadriplegic patient with a complete C-4 lesion, refused surgery and has remained unstable but is asymptomatic.

Most patients managed nonsurgically were treated initially with application of tongs and traction. There were four exceptions to this protocol: two individuals with stable cervical extension injuries involving a central cord syndrome were placed in a cervical collar, and two other patients were placed directly into halo-vest immobilization. In general, patients spent 6 weeks in tongs and traction, although this period was shortened for some individuals, who were placed in halo-vest immobilization and allowed to sit less than 6 weeks after trauma. The more incomplete the spinal cord lesion, the greater was the likelihood of the patient being placed in halo-vest immobilization. Those managed in tongs and traction for the first 6 weeks were all placed in a SOMI brace for the next 6 weeks, and were able to sit.

The results of the neurological examination performed by the most senior physician within the first 24 hours were recorded as the initial data. Although none of the patients had head trauma sufficient to cause loss of consciousness for longer than 2 hours, when consciousness was considered to have been impaired by drugs or alcohol the results of the latest examination within the first 24 hours after trauma were recorded as the initial data. All patients were examined by one of the authors at 3, 6, and 12 months postinjury.

Results

Neurological Improvement

Ten (59%) of the 17 patients with surgical fusion improved neurologically by at least one Frankel class. Six (35%) remained unchanged, and one (6%) deteriorated (Fig. 1 left). Thirty-one (72%) of the 43 patients with autolysis improved neurologically, 11 (26%) remained the same, and one (2%) worsened (Fig. 1 right). Even though the autolysis group tended to show greater improvement, the difference in the percentage of patients who improved between the two groups was not significant ($\chi^2 = 0.99, 1$ degree of freedom). Both patients who worsened dropped from Frankel Class B to Class A. Improvement in neurological function was noted to occur between examinations at all time frames. Five patients first showed recovery at the 6-month review. Four of these patients were initially labeled “complete” injuries (Frankel Class A). One patient was first noted to improve from Class A to Class B at the 12-month examination.

Skeletal Deformity and Stability

Fourteen (82%) of the 17 patients with surgical fusion showed no postoperative spinal angulation throughout the 12-month follow-up period. One patient (6%) exhibited initial angulation, but no progression after 3 months. One patient (6%) had angulation which in-
FIG. 1. Changes in neurological function according to the classification of Frankel, et al.,11 at the initial and the 12-month examinations for 17 patients with surgical fusion (left) and 43 with autofusion (right). The numbers in the boxes to the right of the diagonal line (unshaded) indicate the number of patients who improved. Those on the line remained unchanged and the two patients below the line (shaded) represent loss of function from minimal sensory preservation (Frankel Class B) to no sensory function (Frankel Class A).

creased by 5° between the 3- and 12-month measurements. In one case (6%), data were available only at 3 months after trauma, and this patient was then lost to further follow-up x-ray review. The greatest angulation noted at 12 months for any patient who underwent surgical cervical fusion was 5°.

Of the 43 patients with autofusion, 18 (42%) never developed spinal angulation and five (12%) showed initial angulation which did not progress after 3 months. At 12 months, eight patients (19%) exhibited increased angulation with a mean change of 10°, and seven patients (16%) showed a lessening of angulation with a mean change of 9°. For five patients (12%) data were available only at 3 months. The difference between the surgical fusion and the autofusion groups relative to the development of angulation was statistically significant ($\chi^2 = 7.5$, $p = 0.006$). Considering only the patients in the autofusion group who did develop angulation, the mean angulation at 12 months was 14°. The worst angulation in the entire series (57°) was shown by the patient who underwent laminectomy prior to entering our system of care.

In the surgical fusion group of 17 patients, seven patients (41%) exhibited bone displacement during the 12-month study period, while nine patients (53%) showed none. Data were available at the 3-month post-trauma interval only for the one remaining patient. The range of this variable was 1 to 5 mm with a mean of 3 mm. Bone displacement did not worsen over time in any of these patients, and in two patients (11%) this condition improved by 2 mm during the time of the study. In the group of 43 autofusion patients, 19 patients (44%) exhibited bone displacement and 19 (44%) had none. Bone displacement in the autofusion group ranged from 1 to 11 mm, with a mean of 3 mm and a median of 3 mm. No patient in this group had worsening of bone displacement, and in six patients (14%) the condition improved an average of 2 mm during the 12-month period. No statistically significant difference was found between the data for the two groups.

Reactive bone formation developed anterior to the vertebral bodies in a majority of the patients. Nine (69%) of the 13 patients who underwent surgical fusion via a posterior approach developed radiographically proven reactive bone formation. Similarly, 36 (84%) of the 43 patients in the autofusion group exhibited reactive bone formation anteriorly. The patient who underwent laminectomy at another hospital also showed reactive bone development. When the patients were grouped according to their mechanism of injury, reactive bone formation was noted to be present in all groups but was best visualized in those patients with a mechanism of flexion with compression or of compression alone. Even though the autofusion group tended to show callus formation more than the other group, the difference was significant only at the 0.1 probability level ($\chi^2 = 2.77$, $p = 0.096$).

Spinal instability was determined by comparison of lateral flexion-extension radiographs of the cervical spine. Changes in angulation and subluxation at the spinal injury level were considered determinants of instability. None of the patients who underwent operative fusion demonstrated spinal instability at any time following surgery. Similarly, none of the patients in the autofusion group whose injury was due to extension, compression, or flexion with compression showed late or progressive instability. Only those patients whose injury involved flexion coupled with distraction (that is, those who demonstrated disruption of the posterior ligamentous complex) were at risk for this type of complication. Three (33%) of the nine patients who suffered a flexion with distraction injury developed progressive spinal instability. The patient who underwent prior laminectomy was found to have a stable spine at each examination.

Neurological Outcome Correlated with Skeletal Deformity

An attempt was made to correlate the degree of skeletal deformity with neurological outcome. Patients
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whose x-ray films demonstrated retropulsion of bone fragments into the canal, resulting in spinal canal narrowing, were compared with those whose films did not show this condition. Improvement in neurological function was measured by comparing the initial with the 12-month examination results, based on the Frankel criteria. Within the group of 43 patients managed nonsurgically, neurological improvement was noted in 22 (76%) of the 29 patients with canal narrowing and in nine (64%) of the 14 patients without it. In the group of patients who underwent operative fusion, improvement in neurological function was noted in one (25%) of the four patients with canal narrowing and in eight (62%) of the 13 patients without it. The extent of canal narrowing could not be accurately computed for all cases but was generally comparable among the above groups. The differences within and between both groups were not significant.

Finally, the outcome in patients whose x-ray films demonstrated spinal angulation of less than or equal to 15° was compared with that of patients with x-ray evidence of greater than 15° angulation. In the group of autofusion patients, neurological improvement was found in 24 (75%) of 32 patients who showed angulation of 15° or less and in seven (64%) of 11 who showed greater than 15° angulation. Within the group of patients who underwent operative fusion, there was neurological improvement in 10 (63%) of 16 with 15° or less angulation; the one patient with greater than 15° angulation did not improve. Again the differences were not statistically significant.

The patient with prior laminectomy continued to have a complete lesion (Frankel Class A) throughout the period of observation. That patient demonstrated 57° angulation and 10 mm of displacement, the greatest deformity in the series.

Discussion

The data presented here have demonstrated several points worthy of comment. Several patients had neurological levels located two segments above or below the major bone trauma, but in general the correlation was within one segment of the injury.

Improvement of neurological function was shown to be independent of such factors as surgery (performed primarily for stabilization and realignment in all but one case in this series), angulation, and presence of retropulsion of bone fragments into the neural canal. This finding supports the work of other investigators. Improvement was noted in some patients in all groups, implying that other factors, such as those associated with the initial impact of trauma, are more important in determining the occurrence and degree of recovery than the methods of surgical intervention employed or the morphology of the bone injury. Improvement was noted, as expected, in those patients entering the treatment system who had incomplete spinal lesions, but was also found in patients in both the surgical and nonsurgical groups who initially had complete lesions (Fig. 1). Similar results were reported by Frankel, et al. The difficulty of ascertaining true completeness of the lesion is recognized, however; both the clarity of the sensorium and the inability of the neurological examination to test all the tracts within the spinal cord affect this parameter, particularly at the initial examination.

The patients with surgical fusion fared better than the autofusion group with respect to spinal angulation. However, the angulation in all patients was generally acceptable, since the mean angulation in the autofusion group was 14° and only two patients showed an angulation greater than 25°. In some patients angulation improved between the 3rd and 12th month of the study, most likely due to settling and some remodeling.

Both groups contained patients with displacement of bone structures; this speaks to the difficulties involved in restoring anatomical alignment with either the open or the closed method of management. There was less bone displacement in the surgical fusion group, but displacement was also generally within acceptable limits in the autofusion group in which the mean and median displacement among those who had it was 3 mm.

The frequency of callus formation in patients who sustained cervical injuries was unknown to us prior to this study. Patients in both groups formed callus anteriorly, and posterior surgical fusion did not appear to inhibit this. While the intensity of the reactive bone formation was variable among both populations, its occurrence in the vast majority of patients was surprising. This condition is generally assumed to enhance stability; however, it was noted in two out of three of those with an unstable spine in the nonoperated group. Instability was an infrequent occurrence, but all patients with this finding had flexion-distraction type injuries and they comprised 33% of the patients with this mechanism of trauma. This population is therefore clearly at the greatest risk, regardless of whether they had reactive bone formation anteriorly, since this study shows that the latter does not guarantee spinal stability. Conversely, regardless of the mechanism of injury, the absence of reactive bone formation does not indicate that the lesion will be unstable.

The patient who underwent a prior laminectomy had originally sustained a flexion-distraction injury. He developed moderate reactive bone formation and his spine was stable despite the laminectomy and marked deformity.

The large percentage of patients treated nonoperatively or with posterior fusion who had anterior reactive bone formation would suggest that, when surgery is considered for stabilization, posterior fusion may be the surgical approach of choice in many patients. Individuals undergoing this surgical approach will not only have posterior spinal fusion but also anterior reactive bone formation, so that a “two-column” fusion results.

References

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Manuscript received May 5, 1986. Accepted in final form October 23, 1986. This work was supported in part by the Department of Education, National Institute of Handicapped Research Grant 133NH50014.

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