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Surgical treatment for injuries of the middle and lower cervical spine

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Abstract We reviewed the surgical treatment of 31 patients with burst fractures or teardrop dislocation fractures in the middle and lower cervical spine. Patients were treated with anterior instrumentation, posterior instrumentation, or a combination of both. Patients were evaluated radiographically and with the Frankel neurological outcomes grading scale. Anterior decompression and fusion restored the spinal canal diameter by approximately 60% whereas the posterior or combined approaches restored the canal diameter by only 6%. In addition, nine of 24 patients treated anteriorly gained improved neurological function whereas none of the patients treated posteriorly had neurological improvement. Based on the anatomical and neurological findings, the study demonstrates that anterior fusion is preferable to posterior fusion for the treatment of burst fractures and tear-drop dislocation fractures of the middle and lower cervical spine.

Résumé Nous avons revus le résultat du traitement chirurgical de 31 malades avec une fracture comminutive ou une fracture-luxation en flexion (tear drop) du rachis cervical moyen et inférieur. Les malades ont été traités avec une instrumentation antérieure, une instrumentation postérieure, ou une combinaison des deux. Les malades ont été évalués radiographiquement et avec le score neurologique de Frankel. La décompression-fusion antérieure a restauré le diamètre du canal vertébral approximativement dans 60% des cas, alors que les abords postérieurs ou combinés ont restauré le diamètre du canal dans seulement 6% des cas. De plus, 9 des 24 malades traités par voie antérieure ont vu leur fonction neurologique améliorée, alors qu'aucun des malades traités par voie postérieure n'avait d'amélioration neurologique. Basé sur les conclusions anatomiques

et neurologiques, l'étude démontre que la fusion antérieure est préférable à la fusion postérieure pour le traitement des fractures comminutives et des fracture-luxations en flexion de la colonne vertébrale cervicale moyenne et inférieure.

Introduction

Each year, approximately 13,000 new spinal cord injuries occur in the United States [7]. The most frequently injured levels are in the middle and lower cervical spine. There are some criteria for classifying vertebral body fractures of the middle and lower cervical spine [2]; however, a burst fracture is often mistaken for a teardrop dislocation fracture, as described by Schneider and Kahn [15]. Treating these fractures is sometimes difficult due to the severe damage to the vertebral body and marked instability. Straightforward treatment decisions such as whether to treat such fractures anteriorly and/or posteriorly have not been established. Therefore, the current study assessed and compared the results of treatment of these fractures in 31 patients based on imaging and physical examination findings. The hypothesis of the authors was that burst fractures and tear-drop fractures treated anteriorly would result in a superior outcome to teardrop fractures treated posteriorly.

Patients and methods

From 1986 to 2000, 31 patients were treated at the authors' primary hospital for single-level, high-energy injuries of the middle and lower cervical spine. Compression fractures were excluded. These patients included 11 with burst fractures and 20 with tear-drop dislocation fractures. There were 29 men and two women, age range 14–69 years with a mean of 29.3 years. Duration of follow-up ranged from 6 months to 14 years with an average of 23.5 months. Mechanism of injury was a motor vehicle accident in 21 patients and a fall in the remaining ten. Injured levels had the following distribution: one at C3, two at C4, sixteen at C5, six at C6, and six at C7. All patients wore a Halo-Vest

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for 6 weeks and then a posterior cervical collar for about 3 months. During this period of immobilization, the lamina arch fractures achieved union.

Before 1992, tear-drop fractures were treated posteriorly with Luque rods or Mizuno plates. After 1992, the fractures were treated with anterior decompression and bony fusion.

The patients in this survey were divided into three groups based on fracture type and treatment regimen. All 11 patients with burst fractures underwent anterior decompression and bony fusion and were referred to as the anterior burst (A-B) group. Of the patients with tear-drop dislocation fractures, anterior decompression and fusion were performed in 13 patients, and they were referred to as the anterior tear-drop (A-TD) group. One of these patients also underwent additional posterior fixation. In four cases with severe damage of the posterior arch or tracheotomy, posterior fixation followed by anterior decompression and fusion was done, and three patients underwent posterior fixation alone. These seven patients were referred to as the posterior teardrop (P-TD) group (Table 1).

All anterior fusions were at the interbody level of the injured segment with the exception of one case. Posterior Luque SSI rods were used in all posterior cases except one, in which the Mizuno plate was used. There were four to eight posterior levels instrumented with a mean of 5.4 levels. For burst fractures, bone fragment retroprotrusion was measured on lateral radiographs as the ratio of the anteroposterior (A-P) length of the bone protruding into the canal to the diameter of the canal of the adjacent intact caudal vertebra (Fig. 1a). The amount of retrolisthesis was measured for tear-drop dislocation fractures as the ratio of the A-P width of the posteriorly translated part of the fractured vertebral body to the width of the superior edges

Fig. 1 **a** In burst fractures the percentage of spinal canal compromise was computed as $100 \times b/a$ **b** In tear-drop fractures the percentage of spinal canal compromise resulting from retrolisthesis was computed as $100 \times b/a$

of the adjacent intact lower vertebra (Fig. 1b). Using computerized tomography (CT), the degree of injury to posterior elements was compared based on the mean number of fractured vertebral arches. For evaluation of postoperative imaging findings, the removal rate of bone fragments and the reduction rate were measured on lateral X-ray films for burst fractures and tear-drop dislocation fractures, respectively. Statistical analysis was performed with the Mann-Whitney *U*-test using median values because of large variations in those values. Clinical findings were tabulated using the Frankel's grading scale [6] and motor function by Zancolli's classification (Table 2). Frankel grade (A-E) was converted to a numeric score (1–5) (Table 3).

Table 1 Patient demographics. *A-B* anterior burst group, *A-TD* anterior teardrop group, *P-TD* posterior teardrop group

	A-B group	A-TD group	P-TD group
Number of patients	11	13	7
Average age (years)	26.7	29.3	33.4
Gender			
Male	10	12	7
Female	1	1	0
Mechanism of Injury			
Motor vehicle accident	8	10	3
Fall	3	3	3
Neurologic status			
Average Frankel score preoperative ^a	1.9	2.0	1.0
Cases with complete spinal cord injury	8	9	6
Radiographic status			
Spinal canal compromise (%)	26.4%	29.9%	34.0%
Mean number of laminar fractures	0.8	1.1	2.3

^aThe Frankel grade (A-E) was converted to a numeric score (1–5)

Results

The average amount of bone fragment protrusion of fractured vertebral body into the spinal canal was 26.4% in the A-B group, 29.9% in the A-TD group and 34.0% in the P-TD group, showing no significant differences among the three groups. The mean number of fractured vertebral arches seen on CT scans was 0.8 in the A-B group, 1.1 in the A-TD group and 2.3 in the P-TD group which was significantly higher. The bone fragment reduction rate was 60.2% in the A-B group, and the vertebral reduction rate was 61% in the A-TD group and 6% in the P-TD group. There was no significant difference between the mean reduction rates in the A-B and A-TD groups, but both were significantly greater than that in the P-TD group.

In the A-B group, two patients improved from Frankel grade A to grade B and two patients improved from Frankel grade D to grade E. In the A-TD group, two patients improved from Frankel grade A to grade B and three patients improved from Frankel grade D to grade E. No patients in the P-TD group improved in neurological status.

Table 2 Frankel's grading scale and Zancolli's classification

Frankel's grading scale	
A	Complete: The lesion was complete both motor and sensory below the segmental level.
B	Sensory only: Some sensation was present below the level of the lesion, but motor paralysis was complete.
C	Motor useless: Some motor power was present below the lesion, but of no practical use.
D	Motor useful: Useful motor power below the level of the lesion.
E	Intact: Free of neurologic symptoms.
Zancolli's classification	
C5 A	Without brachioradialis
B	With brachioradialis
C6 A	Weak wrist extension
B	Strong wrist extension
	1. Without pronator teres and flexor carpi radiaris
	2. With pronator teres and without flexor carpi radiaris
	3. With pronator teres, flexor carpi radiaris and triceps
C7 A	Complete extension of ulnar fingers and paralysis of radial fingers and thumb
B	Complete extension of all fingers and weak thumb extension
C8 A	Complete flexion of ulnar fingers and paralysis of flexion of radial fingers and thumb
	Complete thumb extension
B	Complete flexion of all fingers and weak thumb flexion. Weak thenar muscles
	Paralysis of the intrinsic muscles of the fingers without or with flexor superficialis

Table 3 Change in Frankel score from preoperative to postoperative status. *A-B* anterior burst group, *A-TD* anterior teardrop group, *P-TD* posterior teardrop group

A-B group					
Preoperative	Postoperative				
	A	B	C	D	E
A	6	2			
B					
C					
D					2
E					1
A-TD group					
Preoperative	Postoperative				
	A	B	C	D	E
A	7	2			
B					
C					
D					3
E					1
P-TD group					
Preoperative	Postoperative				
	A	B	C	D	E
A	6				
B					
C					
D					
E					1

When patients from all three groups with Frankel grades A or B were evaluated by Zancolli's classification, the level of paralysis was improved in four patients in the A-B group, in three in the A-TD group, but in none in the P-TD group (Fig. 2).

Surgery was performed within 4 days of injury in 26 of the 31 patients; the remaining five patients underwent elective surgery. Among these five patients, two improved from Frankel grade D to grade E while three with Frankel grade A showed no improvement. We could not reach any conclusion concerning the relationship between the improvement of paralysis and the timing of surgery, because of differences in the number of cases and the severity of paralysis between early and elective operations.

The level of complete paralysis was several medullary segments below the damaged vertebral body in four of the eight patients in the A-B group and four out of nine in the A-TD group. In the P-TD group, the level corresponded to one medullary segment below the damaged vertebral body. Lamina arch fractures occurring above the damaged vertebral body did not affect the level of paralysis.

Discussion

There are few methods of classifying acute vertebral body fractures of the middle and lower cervical spine [2]. Despite these classifications, burst fractures are still often misclassified as tear-drop dislocation fractures [8]. Tear-drop fractures are associated with hyperflexion compression injuries, and the fractures primarily involve the anterior and middle columns according to Denis's three-column theory [4]. Since the involved anatomy of tear-drop fractures is

Fig. 2 Improvement in motor function of patients by Zancolli's classification **a** in the anterior burst (A-B) group, **b** in the anterior teardrop (A-TD) group, and **c** in the anterior teardrop (P-TD) group

similar to that of burst fractures and neither involve facet interlocking, the treatment for the two fracture types is similar.

Burst fractures result in vertical compression of the vertebral body and result in protrusion of the posterior vertebral body wall into the spinal canal. On the other hand, tear-drop dislocation fractures result in the shearing of a tear-drop bone fragment from the anteroinferior edge of the vertebral body and the protrusion of the posteroinferior edge into the spinal canal. However, it is sometimes difficult to distinguish between these fractures if a vertebral body is split into two portions or is comminuted. The primary distinction between the two is compression of the middle column as seen in burst fractures, and CT scanning is sometimes necessary for a definite diagnosis.

The mechanism of compression of the spinal cord differs between these two types of fractures as well. In burst fractures, a bone fragment retroprotrudes at the level of the vertebral body affecting the spinal cord whereas in tear-drop dislocation fractures, the vertebral body itself slips posteriorly at an intervertebral level, leading to spinal canal stenosis (Fig. 3).

The measured amount of bone fragment protrusion into the spinal canal showed no significant differences among the three groups. However, there were more fractured laminae in the P-TD group and there were also fewer cases of restoration of the canal space in this group compared with the other two groups.

Prior to 1991, tear-drop dislocation fractures with posterior element disruption were treated with posterior fusion instrumentation and fusion. The results of this demonstrated

that posterior reduction resulted in a poor reduction of the compromised canal and a poor clinical outcome.

According to the Frankel grading scale and Zancolli's classification, neurological function was improved in 12 of the 24 patients in the A-B and A-TD groups, excluding one patient in the A-B group without paralysis. In the P-TD group, no patient had neurological function improvement. Despite the fact that these patients were completely paralyzed, the results of the study demonstrate that activities of daily living (ADL) were improved more in the patients who were treated with anterior decompression compared with those treated posteriorly [17].

Since extensive posterior intervertebral fixation may disturb ADL, it is desirable to minimize the size of the surgical site and the area of fixation as much as possible. The instrumentation used for posterior fixation included Luque rods and Mizuno plates, both of which require a wide exposure for application. Two patients in the current study had disruption of their ADL due to the posterior fixation. Recently, reports have shown that newer transpedicle screws and plates or lateral mass screws and plates are able to achieve fixation within a small area without disrupting the patient's ADL [1, 10].

Our study demonstrates, however, that both burst fractures and tear-drop dislocation fractures should be treated with an anterior fusion when possible. This treatment decision is based on superior decompression achieved from the anterior approach and the subsequent superior clinical results. The number of disrupted posterior levels did not correlate with the clinical outcome as all patients had a poor clinical outcome despite the fact that all laminar arch fractures fused following treatment.

Many studies have discussed the usefulness of spinal column stabilization and spinal cord decompression by surgical treatment using Frankel's classification [3, 11–13, 16]. Koivikko et al. studied the clinical outcomes of cervical burst fractures and flexion teardrop fractures using Frankel's classification and compared the findings with the spinal canal encroachment from retropulsed fragments as determined from radiographs [9]. They compared their results with conservative treatment, and concluded that operatively treated patients recovered more often and presented less spinal canal narrowing than conservatively treated patients. Sapkas et al. reported that there is a correlation between the magnitude of the spinal canal encroachment

Fig. 3 The retropulsion of bone **a** at the vertebral body level in a burst fracture and **b** at the interbody level in a tear-drop dislocation fracture

and the initial neurological deficit [14]. The amount of canal encroachment was also predictive of the clinical outcome.

This study examined the postoperative neurological improvement using the Frankel and Zancolli classifications. Both classifications complement each other and provide a detailed description of the compromise to the patients' symptoms and function. In 1994, the American Spinal Injury Association (ASIA) established a standard neurological classification [5]. The motor index score of ASIA may develop into an international standard from now on.

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