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Selection of the Surgical Approach for Stabilization of Subaxial Cervical Spinal Injuries

Subaksiyal Servikal Spinal Yaralanmalarda Stabilizasyon için Cerrahi Yaklaşımın Seçimi

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ABSTRACT

OBJECTIVE: The objective of this study was to investigate the effects of our surgical treatment method selection criteria for unstable cervical spinal injuries on the clinical outcomes.

METHODS: Forty-seven consecutive patients with traumatic subaxial cervical spine instability were included in this study. All were classified in five groups according to our classification system describing both the mechanism and pathology of the instability. The type of the surgical approach, anterior, posterior or combined, was chosen according to this classification system. A total of 37 anterior, 4 posterior and 6 combined surgeries were performed. The neurological status of the patients was classified according to the Benzel-Larson grading system. Follow-up evaluation included re-grading of the patients' neurological status and also radiographic analyses with plain and dynamic roentgenograms and computerized tomography scans to assess the fusion rate in the late postoperative period.

RESULTS: Fusion was achieved in 38 of 40 patients (95%). Seven patients with total loss of muscle function below the injured level died because of cardiovascular instability and respiratory insufficiency. These patients were not included in the fusion study. The number of patients who had incomplete neurological deficit before surgery and became ambulatory with or without assistance at the late postoperative period was 28 (59.5%). The complications encountered were: two cases of neurological deterioration (all radicular in nature), two cases of pseudarthrosis, one esophagus fistula, six cases of malposition of anterior cervical plate (during the application) and two cases with adjacent level pathology.

CONCLUSION: Our classification system describing both the pathology and the mechanism of the injury is a simple and effective guide for the selection of the surgical approach in the treatment of patients with unstable cervical spinal injury.

KEY WORDS: Cervical trauma, stabilization, subaxial cervical injury

ÖZET

AMAÇ: Bu çalışmanın amacı instabil subaksiyel servikal spinal yaralanmalarda cerrahi tedavi yönteminin seçim kriterlerimizin klinik sonuçlar üzerindeki etkisini araştırmaktır.

YÖNTEM: Bu çalışmaya travmatik subaksiyel servikal spinal instabilitesi olan toplam 47 hasta alınmıştır. Hastaların tamamı instabilitenin hem mekanizmasını hem de patolojisini tarif eden kendi sınıflama sistemimize göre beş grupta değerlendirilmişlerdir. Cerrahi yaklaşımın şekli (anterior, posterior ya da kombine) bu klasifikasyon sistemine göre seçilmiştir. Toplam olarak 37 anterior, 4 posterior ve 6 kombine yaklaşım uygulanmıştır. Hastaların nörolojik durumları Benzel-Larson sınıflamasına göre değerlendirilmiştir. Ameliyat sonrası değerlendirme geç postoperatif dönemde hem nörolojik durumların yeniden değerlendirilmesini hem de füzyon oranını değerlendirmek için düz ve dinamik röntgenogramlar ile birlikte, bilgisayarlı tomografi ile yapılan radyolojik analizleri içermektedir.

BULGULAR: Kırk hastanın otuz sekizinde füzyon sağlanmıştır (95%). Lezyon seviyesi altında tam kas kuvveti kaybı olan 7 hasta kardiovasküler problemler ve solunum yetersizliği nedeniyle kaybedilmişlerdir ve füzyon değerlendirilmesine alınmamışlardır. Ameliyat öncesi nörolojik defisiti olup, geç postoperatif dönemde yardımlı ya da yardımsız yürüyebilen hasta sayısı 28 (%59,5) dir. Karşılaşılan komplikasyonlar; iki nörolojik bozulma (radiküler tipte), iki psödoartroz, bir özefagus fistülü, altı anterior servikal plak malpozisyonu (uygulama esnasında) ve iki komşu disk mesafesinde bozulmadır.

SONUÇ: Yaralanmanın hem patolojisini hem de mekanizmasını tarif eden sınıflama sistemimizin instabil subaksiyel servikal spinal yaralanması olan hastaların tedavisinde cerrahi yaklaşımın seçimi için uygun bir yöntem olduğu tespit edilmiştir.

ANAHTAR SÖZCÜKLER: Servikal travma, stabilizasyon, subaksiyel servikal yaralanma

INTRODUCTION

The diagnosis of cervical spinal instability has become easier with the advances in imaging techniques, but its management still remains controversial. Before the introduction of spinal instrumentation, many of these injuries were managed with traction, postural reduction, or external orthoses. Immobilization with the halo-vest has also been used extensively as a treatment modality to stabilize cervical spinal fractures (32, 33, 37, 48, 52). However, increasing reports of complications associated with the halo fixation and prolonged immobilization and the high failure rates have stirred controversy over which patients are suitable candidates for internal spinal fusion and fixation (3, 9, 17, 28, 40, 41, 44, 47, 49, 60). Besides, there is no consensus on the determining factors for the selection of type of surgical approach (30).

We propose that the mechanism of injury causing instability of the cervical spine, the age of the injury and existence of spinal cord compression will guide the surgeon for the selection of the surgical approach for optimal internal stabilization. The results of surgical approaches selected according to these factors in 47 consecutive patients with a cervical spinal injury were documented.

MATERIAL AND METHODS

Forty-seven consecutive patients who were surgically treated because of traumatic instable subaxial cervical spinal injury between January 1995 and July 2002 were included in this study. Patients with craniocervical junction injury, those who died because of cardiac and respiratory insufficiency before the operation and patients treated conservatively because of a stable injury were not included in this study. The decision of instability was made according to the description of White and Panjabi (70). This patient group consisted of 36 men and 11 women with a mean age of 39 years, ranging from 14 to 82 years. Of the 47 patients, 33 were injured in motor vehicle accidents in which they were occupants, 9 by falling downstairs and 5 by diving accidents. The neurological condition of the patients with regard to myelopathic dysfunction was graded according to the Benzel-Larson (6) grading system (Table I). The systemic examination findings and associated injuries were also recorded. Routine radiographs including lateral, anteroposterior, and open-mouth views and cervical MRI were obtained for all patients in this study. We carefully studied these imaging data to define the details of the injury preoperatively. The features studied were: 1) the level of the injury and the presence of secondary involvement of other adjacent and/or distant levels; 2) the measurement of the degree of angulation in the sagittal and horizontal plane; 3) the direction of subluxation: anterior or posterior; 4) the presence of ligamentous rupture and/or facet joint abnormalities; 5) the presence of spinal cord compression; 6) fracture of individual elements of the vertebrae such as percentage of loss of vertebral body height. The types of injuries in this study were classified in five groups by a new classification system, similar to the classification of Ducker (24), according to both the mechanism and the pathology of the injury (Table II). Penetrating injuries were not included since we did not encounter such an injury.

Table I: Benzel-Larson neurological grading system of thoracic and lumbar spine injuries with regard to myelopathic function (6).

Grade	Description
I	Complete functional neural transection: no motor or sensory function
II	Motor complete: no voluntary motor function w/ preservation of some sensation
III	Motor incomplete-nonfunctional: minimal nonfunctional voluntary motor function
IV	Motor incomplete-functional (nonambulatory): some functional motor control that is useful but not sufficient for independent walking
V	Motor incomplete-functional (limited ambulation): walking w/ assistance or unassisted but w/ significant difficulty that limits patient mobility
VI	Motor incomplete-functional (unlimited ambulation): difficulty w/ micturition: significant motor radiculopathy; discoordinated gait
VII	Normal: neurologically intact or minimal deficits that cause no functional difficulties

The distribution of patients according to this classification system was as follow: Group I: 23 patients (48.9%), Group II: 11 patients (23.4%), Group III: 3 patients (6.3%), Group IV: 6 patients (12.7%) and Group V: 4 patients (8.5%). The majority of the injuries in this study were acute traumas, but there were four patients who were admitted late (two months or more) because of misdiagnosis or referred to our division by another unit due to the failure of external immobilization.

Treatment:

All patients with a neurological deficit received steroid treatment with methylprednisolone administered first as a 30 mg/kg bolus and then an infused at 5.4 mg/kg/h for 23 hours. When instability is diagnosed, the philosophy of our division has been to manage patients surgically. The halo-vest was not used in any of the cases. In general, closed reduction was attempted by skeletal traction with 5 kg initially and the sequential addition of weights in 2.5 to 5 kg increments up to a maximum of 15-18 kg for those patients with dislocation or fracture/dislocation before the surgery. Lateral radiographs of the cervical spine were obtained following each increment of weights until reduction was accomplished. However, skeletal traction was not applied to patients with neural canal encroachment due to a retropulsed bone and/or a disc fragment and severe ligamentous rupture diagnosed at initial MR images. Patients with spinal cord compression underwent surgery at the earliest possible time (most of them within 24 hours after admission), but not on an emergency basis. Surgical fusion was also performed without preoperative skeletal traction in patients with injuries older than one month.

Selection of surgical approach:

Selection of surgical method according to fracture types is summarized in (Table III).

Group I patients: All of these patients were operated on by anterior approaches. The disc space was evacuated and Smith-Robinson (56) type fusion with an autogenous bone graft from the iliac crest and anterior plate-screw fixation was performed to the mobile segment (Figure 1A-1B). Of 19 patients, fifteen were subjected to skeletal traction for reduction of displaced vertebral bodies before surgery. The other four patients had spinal cord compression due to a retropulsed disc fragment diagnosed by initial MR images and underwent surgery without skeletal traction. Reduction of the displaced vertebral bodies and/or facet dislocations could be achieved by manipulations during the surgery in all of these patients after the evacuation of retropulsed disc fragments and release of both anterior and posterior longitudinal ligaments. The reduction maneuver consists of first distracting the dislocated vertebra using the corpus vertebra distracter and then pulling the upper vertebra upward and then downward over the lower corpus vertebra under fluoroscopic control (20, 21, 23).

Group II and III patients: Patients included in these two groups were also operated by anterior approaches. In contrast to the Group I patients, autogenous tricortical iliac crest strut grafting was performed after removal of the crushed vertebra, followed by stabilization using an anterior-cervical plate (Figure 2A-2B-2C). Skeletal traction was

Table II: The Classification of our patients according to both the mechanism and the pathology of the cervical injury (* older than a month).

GROUP I	Flexion type injury, corpus vertebra fracture (-), anterior and/or posterior longitudinal ligament rupture (+). Unilateral or bilateral locked facets may accompany.	
GROUP II	Flexion type injury, corpus vertebra fracture (+), anterior and/or posterior ligament rupture (+). Unilateral or bilateral locked facets may accompany.	
GROUP III	Axial load type injury; burst fractures.	
GROUP IV	**A**	Extension or extension-rotation type injury with superior or inferior facet fractures alone.
	B	Extension-rotation type injury with lateral mass separation fracture alone.
	C	Extension-rotation type injury; anterior ligamentous ruptures with or without avulsion fractures of corpus vertebra accompanied by lateral mass separating fractures or facet fractures.
GROUP V		All old* unstable subluxations or fractures causing alignment deformity.

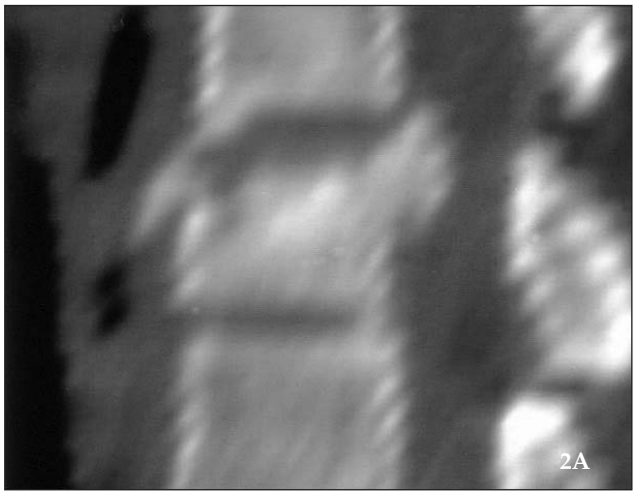
Table III: Selection of surgical method according to the groups.

GROUPS		TYPE OF SURGICAL APPROACH	NUMBER OF CASES
GROUP I		Anterior approach. Smith-Robinson type fusion and anterior plate-screw fixation.	23 (48.9%)
GROUP II		Anterior approach. Removal of crushed vertebra, fusion with autogenous iliac crest strut graft and anterior plate-screw fixation.	11 (23.4%)
GROUP III		Anterior approach. Removal of crushed vertebra, fusion with autogenous iliac crest strut graft and anterior plate-screw fixation.	3 (6.3%)
GROUP IV	**A**	Posterior approach. Lateral mass screw fixation.	3 (6.3%)
	B	Posterior approach. Lateral mass screw fixation.	1 (2.1%)
	C	Combined approach. Smith-Robinson type fusion, anterior plate-screw fixation and posterior lateral mass screw fixation.	2 (4.2%)
GROUP V		Combined approach.	4 (8.5%)

Figure 1: A C4-C5 dislocation due to a flexion type injury (Group I patient), **A:** Preoperative MRI shows severe ligamentous injury and neural canal encroachment (preoperative skeletal traction was not carried out due to retropulsed disc fragment), **B:** Postoperative lateral plain roentgenogram shows Smith-Robinson type fusion and anterior plate-screw fixation.

applied to none of the patients in Group II and III before surgery. It must be noted that patients with a minor corpus vertebra fracture, which does not cause loss of vertebral body height, were subjected to the same surgical approach as for Group I and a Smith-Robinson type fusion was performed instead of total corpectomy.

Group IV patients: Injuries due to extension-type forces cause fractures of posterior vertebral elements. We categorized these fractures in three subgroups: A) facet fractures alone, B) lateral mass separating fractures alone, C) anterior ligament



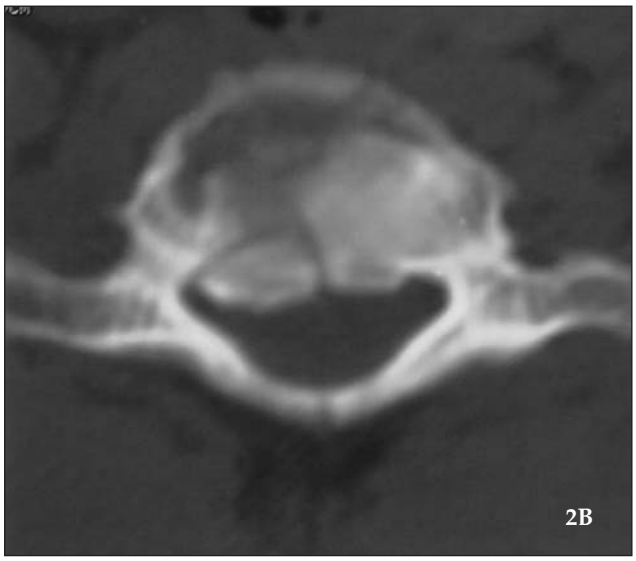
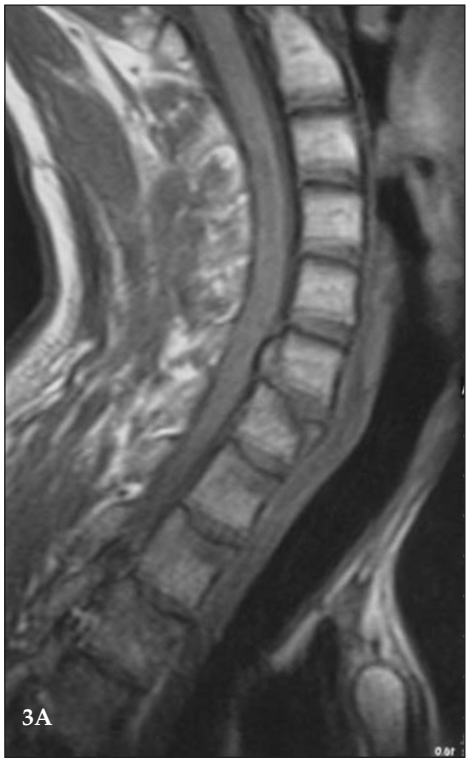


Figure 2A-2B: Preoperative sagittal **(A)** and axial **(B)** CT scans show an illustrative case of cervical burst fracture at C7 level (Group III patient).

Figure 2C: Postoperative sagittal T1-weighted MRI shows solid bone fusion between C6 and T1 with normal cervical configuration.

ruptures with or without avulsion fractures of corpus vertebra accompanied by lateral mass separating fractures. Combined approach with anterior cervical plate and posterior lateral mass screw fixation was performed for group IVC type of injuries because of severe instability of both anterior and posterior columns or retropulsed disc and/or bone fragments causing anterior spinal cord compression (Figure 3A-3B-3C). There were three (6.3%) patients in Group IV B and C, and a combined approach was employed in two (4.2%) of them. Combined approach for this group includes decompression of the spinal cord when necessary, Smith-Robinson type fusion to the mobile segment and anterior plate screw fixation, followed by lateral mass screw fixation by the posterior approach in the same section. Skeletal traction was not applied to any of patients in Group IV. On the other hand, the posterior approach for group IVA and IVB patients only included lateral mass screw fixation.

Group V patients (Late admission): This group includes patients with injuries older than a month. These patients' symptoms arise from the compression of neural structures. Severe neck pain may be present due to the loss of normal cervical



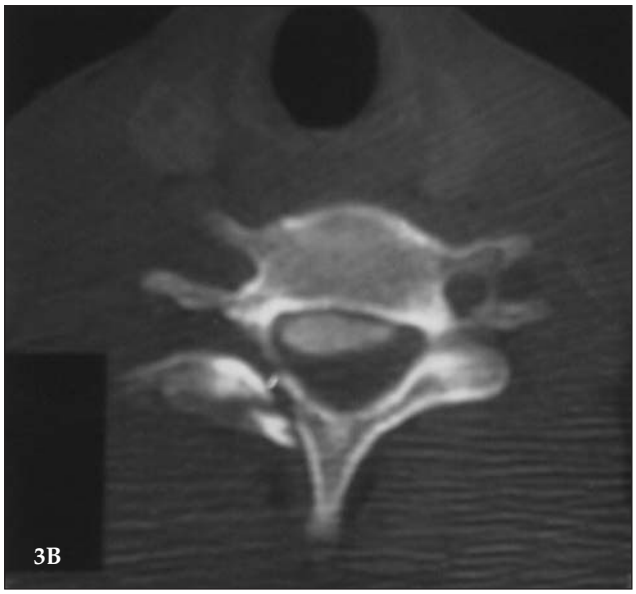


Figure 3A-3B: An illustrative case of Group IV-C patients. Anterior ligamentous rupture with an avulsion fracture of the corpus vertebra due to extension type forces is seen at sagittal T1-weighted MRI **(A)**. Preoperative axial CT scan shows lateral mass separating fracture and neural canal compression due to a retropulsed bone fragment **(B)**.

alignment following the trauma. Thus, whatever the type of injury except burst fractures, surgical intervention must involve release of both anterior and posterior callus tissue and ligamentous structures through a combined approach to be able

Figure 3C: A combined approach was performed for reconstruction of three-column deficiency and neural canal decompression

4A: Cervical spinal MRI was performed and a misdiagnosed C7-T1 dislocation was determined (Group V patient)

to correct the displaced vertebral bodies and/or facet dislocations. Combined approach includes three stages in a single operation: 1- Release of posterior elements (posterior approach). 2- Release of anterior elements and when necessary decompression of the spinal cord, followed by reduction and fusion with anterior plate-screw fixation under fluoroscopic control (anterior approach). 3- Lateral mass plate screw fixation (posterior approach). There were four patients in this group and all of them were operated by the combined approach (Figure 4).

Follow-up Evaluation:

All the patients who had incomplete neurological deficit with sufficient respiratory function were placed into a physical therapy and rehabilitation program, and those with sufficient muscle strength were mobilized as soon after surgery as possible. All patients used a Philadelphia cervical collar for approximately 3 months. The use of the collar was discontinued on an individual basis according to the decision of the attending surgeon. Long-term follow-up evaluation consisted of re-grading the patients' neurological status according to the Benzel-Larson (6) grading system, radiographic analyses of plain and dynamic roentgenograms including flexion-extension and oblique views, and obtaining CT scans to assess fusion 6, 12 and 18 months following the surgery. This standard radiological follow-up was completed in 33 of the 47 patients. Seven of the remaining 14 patients died within one month while two refused further follow-up after 6 months and another five after 12 months. The mean follow-up time was 28.3 months, ranging from 6 to 42 months.

Table IV: The levels of injuries according to type of injury.

Type of injury		LEVELS					TOTAL
		C3-C4	C4-C5	C5-C6	C6-C7	C7-T1	
GROUP I		2	6	10	4	1	23
GROUP II		1	4	5		1	11
GROUP III					2	1	3
GROUP IV	A		1	2			3
	B					1	1
	C		1		1		2
GROUP V				1		3	4
TOTAL		3	12	18	7	7	47

RESULTS

Anterior instrumentation was performed in 37 patients with a Synthes type (27, 55) cervical plate with 2 screws above and 2 screws below the mobile disc segment. Posterior stabilization was performed in 4 patients with lateral mass screw fixation of the unstable segment and also one disc level above and below the unstable segment. The combined approach was used in 6 patients. Both anterior and lateral mass plate-screw fixation were performed in all patients except one where only lateral mass screw fixation was used. The levels of injuries according to our classification system are presented in Table IV. An autogenous tricortical iliac crest strut grafts were used for anterior fusion in all patients who underwent an anterior surgical approach and no supplemental bone grafting was performed after lateral mass screw fixation. However, the facet joints were roughened by curettage to stimulate spontaneous arthrodesis. Loss of correction more than three degrees at final follow-up was observed in 14 patients who were operated by the anterior approach alone. This finding was observed with degeneration of disc spaces adjacent to the fused segment and was clinically symptomatic in two patients with severe neck pain, but none of these patients showed neurological deterioration due to reduced alignment. Of the fourteen patients, only four were under forty years old and reduction of the degree of kyphosis was observed in all after one year of follow-up. The area of degeneration was observed at the upper level of the fused segment in most patients. However, loss of correction was not observed at long-term follow-up in patients operated on by the posterior approach alone or by the combined approach . Fusion was achieved in 38 (95%) of the 40 patients within six months and this was demonstrated by long-term radiographic and clinical follow-up. The 7 patients who died within one month after the operation were not included in the assessment of fusion. The complications encountered were; two cases of neurological deterioration (both radicular in nature), two cases of pseudarthrosis due to infection in Group I patients, one esophagus fistula, six cases with malposition of the anterior cervical plate (during the application) and two cases with severe neck pain due to degeneration of disc spaces adjacent to the fused segment causing deterioration of alignment. Two patients with pseudarthrosis due to infection

Figure 4B,C: (B) Lateral cervical roentgenogram aftersurgical treatment through combined approach. **(C)** Postoperative T2-weighted sagittal cervical spinal MRI of the patient.

underwent a second operation for the removal of the anterior fixation system and appropriate antibiotic treatment was given. Posterior stabilization was employed for both patients after the infection healed.

In this study, 6 patients with complete spinal cord injury and 1 patient with Benzel-Larson Grade 2 died because of cardiovascular instability and respiratory insufficiency. The overall mortality ratio of this study was 14.8% and neurological improvement occurred in 28 of the 47 patients. The total number of patients becoming ambulatory with or without assistance at the late postoperative period was 28 (59.5%). No difference was observed in 14 (includes seven deaths) patients with complete or incomplete neurological deficit six months after the operation, and 5 patients were already grade VII before the operation. There was a statistically significant difference between the preoperative and postoperative Benzel-Larson grades (Paired Sample Test, $p<0.001$, $t=7.418$, Figure 5).

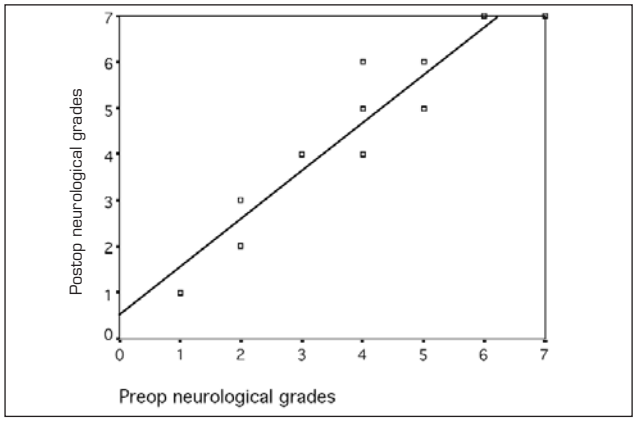


Figure 5: The preoperative and follow-up neurological grades according to the Benzel-Larson grading system (Paired Sample Test, $p<0.001$, $t=7.418$).

DISCUSSION

Restoration of normal anatomic alignment, decompression of neural elements, and achieving spinal stability are the primary goals when treating patients with spinal cord injury. Although several clinical series using surgical and conservative treatment methods have been published, there is insufficient evidence to recommend treatment standards and guidelines for the stabilization of subaxial cervical spinal injuries (30). Selection of the surgical approach is also controversial when surgery is needed (44). As it is well known that failure of immobilization of spinal injuries can occur in a halo-vest (9, 17, 28, 41, 44, 49, 60), all unstable cervical injuries were treated with internal fixation in this study.

Appropriate treatment of fractures of the cervical spine requires detailed radiographic and neurological evaluation of the injury, and determination of the spinal instability. Careful preoperative assessment of the mechanism of injury as well as the resulting bony and ligamentous injuries to guide the treatment are essential. Thus, the classification system to be used to provide guidance while selecting the treatment model must provide information about the pathology as well as the mechanism of the injury. This is the reason why we used a different classification system that uses the pathology occurring after the trauma in addition to the mechanism of the trauma. However, the previous classification systems described in the literature generally classify injuries according to the mechanisms of the injury alone (2, 16, 24).

Effects of the type of optimal surgical fracture stabilization on clinical outcome remain controversial. While some authors assert the superiority of lateral mass fixation systems (15, 67), others advocate anterior plate screw systems (29, 44) or combined systems (12, 19, 66, 68, 69) for biomechanical stability. In our opinion, it is more important to fix the actual pathological component causing the instability than concentrate on the fixation system. Our general concept for the selection of the surgical approach is through the side of pathology according to three-column model. Flexion type injuries (Group I and II) produce anterior annular and anterior longitudinal ligament disruption and/or vertebral corpus fracture under tension, which results in a more severe injury to the anterior and middle columns, leaving the cervical spine in some degree of kyphotic angulation (39). We operated on these patients using anterior plate-screw fixation. In our opinion, Group I patients with locked facets should also undergo operation by the anterior approach because of three main reasons: 1) Reduction of subluxation is easier after the release of anterior longitudinal ligaments, 2) these injuries are generally accompanied by an anterior retropulsed disc fragment and its removal can only be possible by the anterior approach, 3) the anterior approach is simple and less traumatizing and can be performed with the patient in the normal dorsal decubitus position, with a skull traction device in place. On the other hand, some authors advocate the posterior approach for this type of injury (26, 59).

Unilateral or bilateral facet fractures may occur as a result of pure extension type injuries or flexion-rotation type injuries also causing anterior column instability. Levine (42) et al divides these fractures into three types: fracture of superior facet, fracture of inferior facet and fracture separations of the articular mass. We used the posterior approach for pure extension or extension rotation type injuries causing only facet fractures. Patients with both facet fracture and anterior column instability were operated only by the anterior approach. However, superior facet fractures can cause radiculopathy. Thus, when radiculopathy is present in patients with superior facet fractures accompanying anterior column deficiency, the combined surgical approach should be employed. On the other hand, fracture separations of the articular masses of the cervical spine have been attributed to a hyperextension and rotation injury and thus differ from other fractures of the articular processes (42, 71, 73). They must be operated using the posterior approach since they are a posterior injury. Complete avulsion of the anterior ligamentous structures with significant anterior disruption due to extension forces can be seen less commonly in addition to the facet or lateral mass separating fractures (53). These are three column injuries causing a high degree of instability and require a combined approach (Figure 3). Few clinical studies outlining indications for combined anterior and posterior stabilization following trauma to the cervical spine are available (12, 19, 66, 68, 69). This technique is generally advised for patients with severe three-column instability as mentioned above. However, it is also required for patients with injuries older than a month. These patients first need a

releasing procedure, both from anterior and posterior, for correction of the deformity during the operation. Since removing these bone spurs and hardened ligamentous structures will enhance the instability, combined fusion and fixation will be necessary for stabilization.

The good anatomic alignment and sufficient stabilization results obtained in our study were compared with the results of previous published clinical series concerning other conservative and operative treatments. The number of patients with final optimal stability shows similarities with good results after surgical fusion and internal fixation in the literature (1, 4, 26, 28, 29, 34, 55, 59, 63). However, the results are not similar to those of patients treated by conservative means or surgically without internal fixation. Koivikko et al reported that 29% of the 55 patients they treated conservatively required surgery later on because of chronic instability or unacceptable anatomical results (38). Closed reduction could not be maintained in about 28% of patients with cervical fracture dislocation injuries with external immobilization (112 of 393 patients) (7, 9, 10, 11, 13, 18, 28, 31, 43, 45, 46, 51, 57, 58, 60, 62, 63, 64, 72). On the other hand, Kewalrami and Riggins (35) studied 44 patients with anterior fusion, but without osteosynthetic plate fixation and found significant fusion problems in 50% of their patients. Although anterior fusion with plate screw fixation has been used widely for cervical spine instabilities since the 1950's as reported by authors such as Bailey and Badgley (5), Dereymaeker and Mulier (22), Southwick and Robinson (65), and Cloward (14), there are few articles concerning its long-term clinical results (1, 19,27, 29, 44, 55). Goffin et al (29) obtained excellent realignment of the cervical spine in 93% of 41 patients with anterior fusion and plate fixation and there was no patient with final postoperative instability among the patients with posterior instability treated by the anterior technique. In our study, the majority of the patients (78.7%) were treated through an anterior approach with plate screw fixation. Long-term results of these patients are similar to the report by Goffin (29) with a 95.7% union rate. However, we observed poor anatomical alignment in 14 (29.7%) patients due to the degeneration of lower and upper adjacent disc spaces after anterior fusion and fixation despite solid bone fusion, and two of them were symptomatic with significant chronic neck pain. In contrast to anterior fusion and fixation, good anatomical alignment was maintained in all patients after the combined approach. Roy-Camille et al (59) reported the use of lateral mass plates in 221 patients with instability of the lower cervical spine. In their series, 14.8% of patients had loss of correction and between five to twenty degrees of kyphosis long-term. In another consecutive series of lateral mass screw fixation, Fehlings et al (26) observed a 93% fusion rate and 13.6% residual kyphosis with an average follow-up period of nearly 4 years. In our series, there were only four patients who were operated with the posterior lateral mass fixation alone and none of them showed residual kyphosis or non-union during long-term follow-up.

As already mentioned in the results section, the mortality rate of this study was 14.8% and all six patients within the complete transverse lesion group died. Bohlman (8) observed in their series of 229 patients a mortality of 46% for the complete transverse lesion group and a mortality of 18% for the incomplete transverse lesion group. Kiwerski et al (36) noted in their series of 1000 patients an overall mortality of 16.7% and a mortality rate of 33% for the group with complete lesions. These results are similar to the studies of Senegas et al (61), Ducker et al (25), and Reynier et al (54). Our mortality rate is high in the complete transverse lesion group when compared with these studies.

Careful preoperative assessment of the traumatized cervical spine classically begins with anterior-posterior and lateral radiographs, which detail bone pathology and gross dislocations. However, these studies may be insufficient since significant ligamentous instability may exist in the absence of an obvious vertebral column fracture/dislocation (2). An anterior longitudinal ligament disruption is especially difficult to detect with plain radiographs, but may be suspected in distractive flexion injuries. Dynamic roentgenograms of the cervical spine can be used in the evaluation of this potential. Nevertheless, this type of investigation may be risky in a patient with a high degree of instability of the cervical spine. Advanced imaging techniques (CT and MRI) are crucial for the no-risk identification of a ligamentous disruption and a neural canal compromise due to a retropulsed disc or a bone fragment and guide the surgeon to select the surgical approach suitable to the particular injury. In our opinion, skeletal traction

must also be employed after MRI since direct roentgenograms do not reveal a severe ligamentous injury or neural canal compromise due to a retropulsed disc or bone fragment (Figure 1A). In such a patient, skeletal traction can cause catastrophic results. In this study, MR images of all of the patients were obtained and patients with severe ligamentous injury and spinal cord compression due to a retropulsed bone or disc fragments underwent surgery and open reduction after a decompression procedure without skeletal traction. These patients had a neurological deficit of Benzel-Larson grade V or below and they underwent surgical decompression within 24 hours. Thus, early MRI played an important role in determining the time of surgery. On the other hand, patients with neural canal compression due to a misalignment of cervical spine benefit from skeletal traction.

CONCLUSION

The column affected by injury according to the three-column theory, the presence of a retropulsed bone or a disc fragment causing spinal cord compression and the age of injury are the most important factors guiding the selection of the surgical approach for patients with subaxial cervical spine instabilities. CT and MRI are mandatory for determining these factors.

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