The Management of Traumatic Spondylolisthesis of the Axis*

BY ALAN M. LEVINE, M.D.†, AND CHARLES C. EDWARDS, M.D.†, BALTIMORE, MARYLAND

From the Spinal Injury Clinic, Division of Orthopaedic Surgery, University of Maryland Hospital, Baltimore

ABSTRACT: **Fifty-two patients with traumatic spondylolisthesis of the axis were admitted to the University of Maryland Spinal Injury Center between 1977 and 1982. There were fifteen Type-I fractures, twenty-nine Type-II fractures, three Type-IIa fractures, and five Type-III fractures. Associated neurological deficits were found in only four patients, although unassociated neurological deficits such as closed head injury were seen in eleven patients. Thirteen patients had other fractures of the cervical spine. Type-I fractures were stable injuries and were treated with collar protection. Most Type-II injuries were reduced with the patient in halo traction, and then immobilization in a halo vest was used. Type-IIa injuries, as they showed increased displacement in traction, were reduced with gentle extension and compression in a halo vest. Type-III injuries were grossly unstable and required surgical stabilization. All of the fractures healed, although the use of early halo-vest immobilization for displaced fractures resulted in significant residual deformity. The radiographic patterns of the fracture types and the resulting data on clinical stability suggested a correlation between the fracture type and the mechanism of injury. Type-I injuries resulted from a hyperextension-axial loading force; Type-II injuries, from an initial hyperextension-axial loading force followed by severe flexion; Type-IIa injuries, from flexion-distraction; and Type-III injuries, from flexion-compression.**

Traumatic spondylolisthesis of the axis (second cervical vertebra) is also referred to as a hangman's fracture[10]. The fracture line usually passes through the neural arch of the axis and may or may not result in anterior displacement of the second cervical vertebra on the third. The injury is most commonly caused by a motor-vehicle accident or a fall. Some authors[4] have considered traumatic spondylolisthesis of the axis to be a flexion injury because of the forward displacement of the second cervical vertebra, while others[2,5,6,11] have considered it to be primarily a hyperextension-axial loading injury. Although the radiographic appearances are similar, the mechanism causing traumatic spondylolisthesis most certainly differs from that described for the hanging injury[7,8,13,14]. The injury produced by a judicial hanging, with the knot in the submental position, results in a bilateral axis-pedicle fracture with complete disruption of the disc and the ligaments between the second and third cervical vertebrae by severe hyperextension and distraction.

Two different classifications of traumatic spondylolisthesis of the axis have been proposed. That of Francis et al., based on the criteria of White and Panjabi, defined categories delineated by limits of 3.5 millimeters of translation and 11 degrees of angulation. The other, described by Effendi et al., is based on radiographic patterns classified as Types I, II, and III. Although both groups proposed that treatment could be based on their classifications, opinions have varied regarding the optimum initial treatment. Cornish considered this to be a grossly unstable fracture and recommended surgical stabilization, while others[2,5,6] have recommended use of the halo vest.

The present study consisted of a series of patients with traumatic spondylolisthesis of the axis who were all treated at one institution. The fractures were classified according to a modification of the system of Effendi et al. and the results of treatment were analyzed in relation to the modified classification. Based on the results of this study, we have identified four different mechanisms of injury and propose a modified four-type classification, together with a treatment approach for each type.

Materials and Methods

Fifty-two patients with traumatic spondylolisthesis of the axis were admitted to the University of Maryland Hospital between 1977 and 1982. There were thirty-six male and sixteen female patients, and the mean age was 35.4 years (range, twelve to eighty-one years). The cause of injury was a vehicular accident in twenty-seven patients, a fall in twenty-one, and an athletic injury in four (Table I).

The injuries were classified on the basis of pre-treatment lateral radiographs of the cervical spine made with the patient supine. Anteroposterior and open-mouth radiographs were also made of all patients at the time of admission. Eleven (21 per cent) of the patients also had lateral tomograms, either to clarify the nature of the injury or to define or rule out additional cervical-spine injuries, or both, and computer-assisted tomography scans were available for five of the patients (10 per cent). The fracture deformity was

* Read at the Annual Meeting of the Cervical Spine Research Society, New York, N.Y., December 3, 1982, and in part at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Atlanta, Georgia, February 10, 1984.

† Division of Orthopaedic Surgery, University of Maryland School of Medicine, 22 South Greene Street, Baltimore, Maryland 21201.

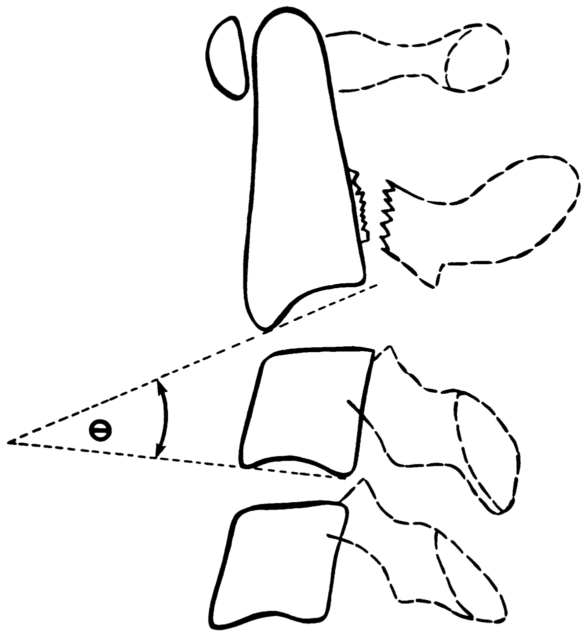

FIG. 1

Angulation is calculated as the angle between the inferior end-plate of the second cervical vertebra and the inferior end-plate of the third cervical vertebra.

described in terms of both the degrees of angulation and the amount of translation between the second and third cervical vertebrae. Angulation was measured by the angle subtended by lines drawn along the inferior end-plate of the second cervical vertebra and the inferior end-plate of the third cervical vertebra (Fig. 1). Anterior translation was measured by the distance between a line drawn parallel to the posterior margin of the body of the third cervical vertebra and the posterior margin of the body of the second cervical vertebra at the level of the disc space between the two vertebrae (Fig. 2). The fractures were then classified into four types. The fifty-two patients in this series had fifteen Type-I injuries, thirty-two Type-II injuries (of which three were Type IIa), and five Type-III injuries. All patients had a neurological evaluation on admission as well as evaluation for other injuries.

TABLE I

CAUSE OF INJURY

Type I		Type II		Type III	
Cause	No.	Cause	No.	Cause	No.
Fall	8	Automobile	18	Automobile	1
Automobile	3	Fall	12	Motorcycle	1
Motorcycle	3	Motorcycle	1	Fall	1
Diving	1	Diving	1	Athletics	2

Type I (Fig. 3) included all non-displaced fractures and all fractures that showed no angulation and less than three millimeters of displacement. For these fractures, physician-supervised flexion-extension radiographs subsequently were made to assess their stability. They were made only if the patient was neurologically intact, fully awake, and alert. All of the Type-I fractures were found to be stable, with no additional displacement occurring on flexion but with varying degrees of reduction occurring on extension.

The Type-I injuries were in nine male and six female patients. The mean age was 41.4 years. Falls and vehicular accidents accounted for almost all of the injuries (Table I). Five patients had lacerations on the face or frontal part of the skull and one had a laceration in the occipital region. Although five patients had a neurological deficit, none of the deficits were associated with damage to the cord at the level of the second and third cervical vertebrae; they were due to a closed head injury in three patients, an anterior cord syndrome in one, and a central cord syndrome in one. In addition, there were eight other major associated fractures of the cervical spine and two minor associated fractures (Table II).

Type-II fractures (Fig. 4) showed significant angulation and translation. Within the Type-II group of Effendi et al., we identified a subset of injuries that have slight or no translation but very severe angulation. We have designated these as Type IIa (Fig. 5). The Type-IIa pattern appears to have a different mechanism of injury and different treatment requirements than the typical Type-II injury. Serial radiographs showed both the Type-II and the Type-IIa injuries to be unstable. Twenty-nine patients had a Type-II injury and three had the Type-IIa variation. There were twenty-two male and ten female patients, whose mean age was 33.2

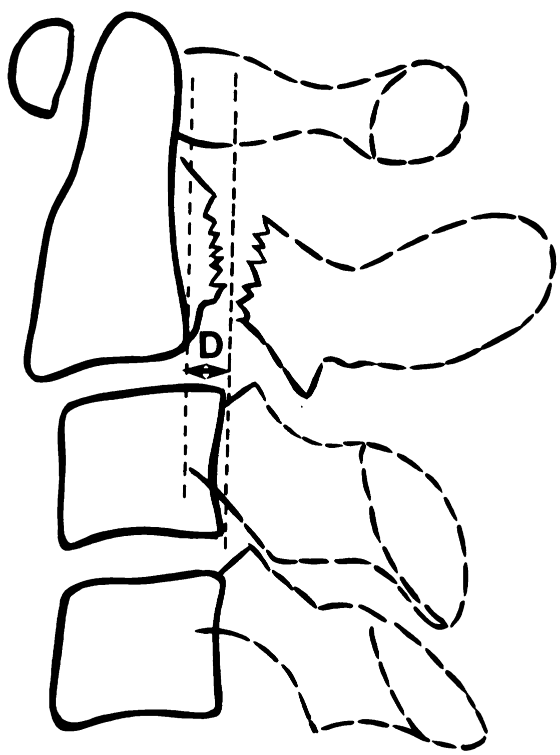

FIG. 2

Anterior translation is measured as the distance between a line drawn parallel to the posterior margin of the body of the third cervical vertebra and the posterior margin of the body of the second cervical vertebra at the level of the disc space between the second and third cervical vertebrae.

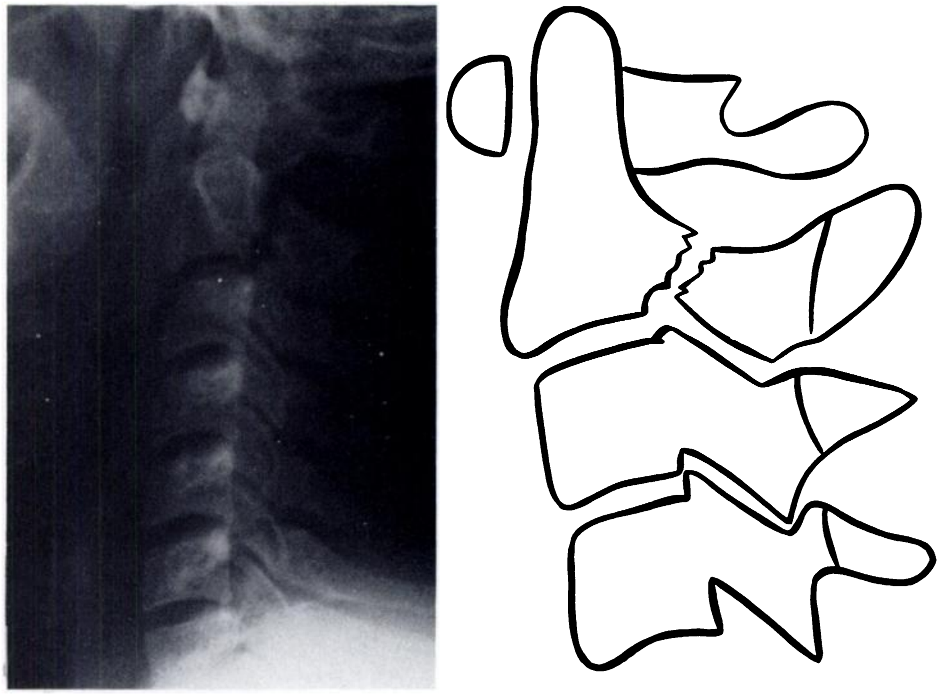

FIG. 3

Type-I injuries have a fracture through the neural arch with no angulation and as much as three millimeters of displacement.

years. The majority of injuries were related to vehicular trauma, although twelve were due to a fall (Table I). Nine patients had lacerations of the face or the frontal area of the scalp, two had lacerations of the posterior area of the scalp, and two had both anterior and posterior lacerations. No relationship was found between the presence or location of the lacerations and abrasions and the type or displacement of the fracture. Five patients had a significant neurological deficit. One patient had a Brown-Séquard syndrome related to the level of the injury, but the neurological changes in the others were due to closed head injury.

There were numerous associated fractures of the cer-

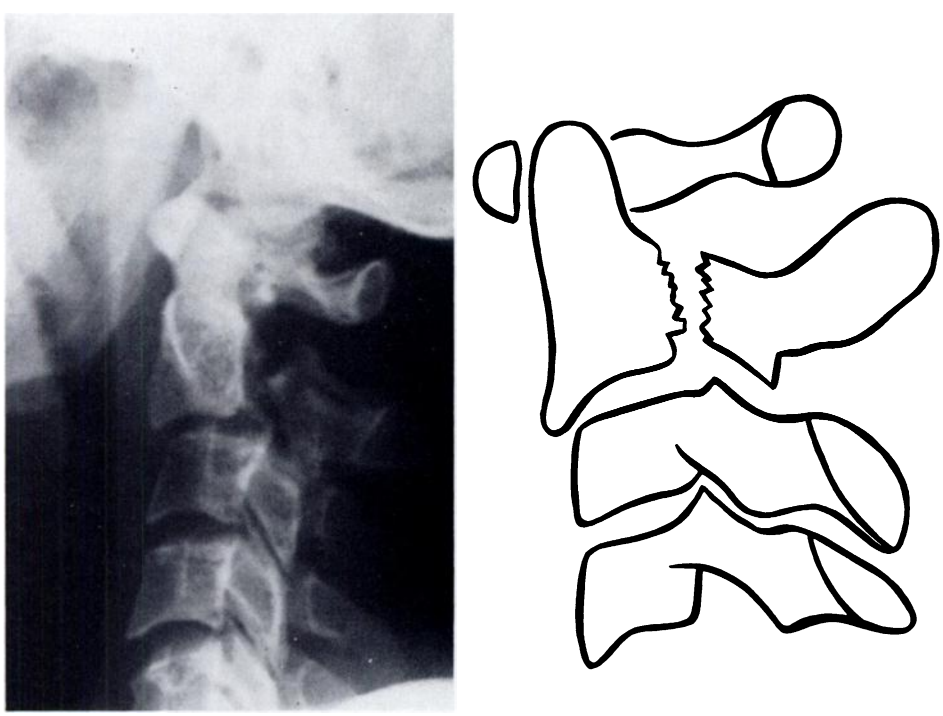

FIG. 4

Type-II fractures have both significant angulation and significant displacement.

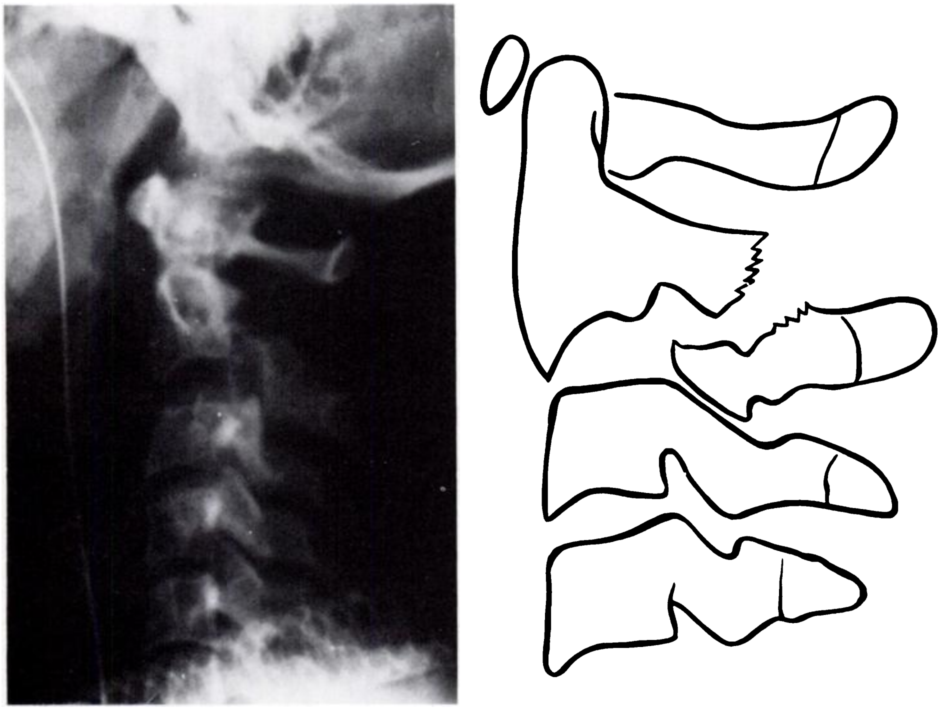

FIG. 5

Type-IIa fractures show minimum displacement but there is severe angulation, apparently hinging from the anterior longitudinal ligament.

vical spine in this group (Table II), although serious ones were less common than in the patients with a Type-I injury. Unlike the patients with a Type-I injury, twenty-two of the twenty-nine patients with a Type-II lesion had significant wedge compression of the anterosuperior portion of the body of the third cervical vertebra. No patient with a Type-IIa injury had such wedge compression. In addition, there was only one avulsion fracture from the anterior portion of the body of the second or third cervical vertebra.

Type-III injuries (Fig. 6) showed both severe angulation and displacement and concomitant unilateral or bilateral facet dislocations at the level of the second and third cervical vertebrae. All of these patients were male, and the mean age was 31.8 years (range, sixteen to fifty-seven years). The causes of injury (Table I) were both vehicular and athletic accidents. There were no associated facial or scalp lacerations and no other associated injuries of the cervical spine. Three of the patients had a neurological defect related to the level of the injury, including one central cord syndrome, one third cervical radiculopathy, and one diffuse weakness of the right upper extremity. The neurological deficits in the other two patients were unrelated to the level of injury and were due to closed head trauma.

TABLE II

ASSOCIATED INJURIES OF THE CERVICAL SPINE*

Type I		Type II	
Injury	No.	Injury	No.
Type-II odontoid	2	Posterior arch of C1	1
Type-III odontoid	1	Spinous process fracture	2
Lateral mass of C1	1	Compression fracture of C4	1
Posterior arch of C1	1	Compression fracture of C6	1
Jefferson fracture	2	Anterior compression fracture of C3	22
Fracture of body of C7	1		
Anterior compression fracture of C3	2		

* There were no associated injuries in patients with a Type-III injury.

Early in the series, treatment of the injury was based on the preference of the individual surgeon, with patients who had a minimally displaced fracture being treated in a collar or halo vest and those who had a more displaced fracture being placed in halo traction. With the accumulation of data, a more consistent treatment pattern evolved. Patients with either less than three millimeters of translation or stability demonstrated on flexion-extension radiographs, or both, were placed in a cervical collar. Those with more displacement and instability were placed in cervical-tong traction on a Stryker frame. Reduction was achieved by the use of 6.8 to 9.1 kilograms of longitudinal traction and a small towel roll placed beneath the mid-portion of the neck.

Once reduction was achieved in a Type-II fracture, the patient was maintained in traction for five to seven days. The weights were then removed and a lateral radiograph was made with the patient supine. If the reduction was adequately maintained, the patient was placed in a halo vest. If, in a more severely displaced Type-II injury (more than six millimeters of translation), the reduction was lost when the weights were removed, the patient was kept in traction for four to six weeks, until the fracture became stable and the weights could be removed without significant loss of position.

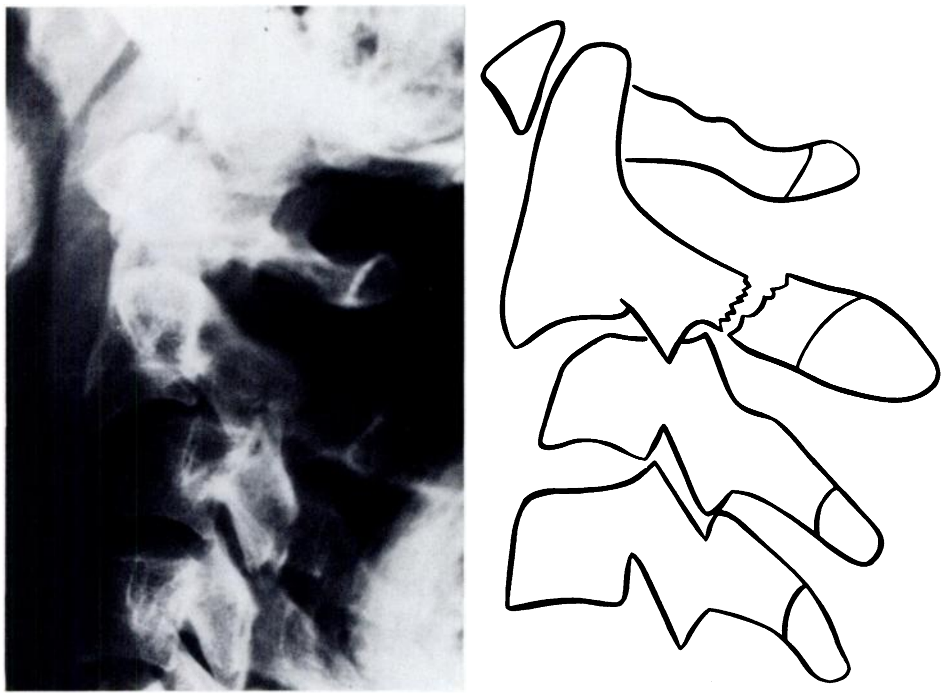

FIG. 6

Type-III axial fractures combine bilateral facet dislocation between the second and third cervical vertebrae with a fracture of the neural arch.

The patients with a Type-III injury underwent surgical stabilization for one of two indications. If the fracture of the neural arch was anterior to either the unilateral or the bilateral facet dislocation, the dislocation was irreducible closed. In that situation, the facet dislocation was reduced and stabilized directly at the time of surgery, and the fracture of the neural arch was allowed to heal with external immobilization. If the fracture of the neural arch was at the level of the facet dislocation or just posterior to it, reduction could sometimes be achieved, but then would be lost because of the instability of the fracture, and therefore surgical stabilization was indicated.

After discharge from the hospital, the patients were evaluated monthly for the first six months and every three months thereafter. Radiographic healing was recorded as having occurred when bone trabeculation could be seen across the fracture sites. Clinical healing was considered to be present when tenderness and pain had resolved and flexion-extension radiographs with the patient out of all immobilization did not demonstrate any motion, either as translation or as an increase in angulation between the second and third cervical vertebrae. Most patients were followed periodically at three-month intervals until two years after injury.

Non-union was diagnosed if residual motion and increased displacement were seen at the fracture site after four months of immobilization. The results of treatment were evaluated on the basis of neurological improvement or deterioration, maintenance of reduction, and union of the fracture, as well as on clinical parameters such as range of motion, pain, paraspinous spasm, and symptoms with barometric changes.

Results

Type-I Injuries

All fifteen of the patients with a Type-I injury had no angulation and less than two millimeters of translation on admission, and the lesions were initially thought to be stable as judged from flexion-extension radiographs. Six patients were subsequently treated in a Philadelphia cervical collar with plaster reinforcement and seven, in a halo vest. One of the seven patients, who had a concomitant unstable fracture of the odontoid, had surgery to stabilize that fracture and then was treated with halo-vest immobilization. Two patients died of other injuries before they were discharged from the hospital, and the remaining thirteen were followed. The mean duration of treatment in a cervical collar was sixty days and the mean duration of immobilization in a halo vest was seventy-five days. No Type-I fracture had a change in the amount of displacement (angulation or translation). There was no difference between the two treatment groups with regard to time to union, rate of union, neck pain, range of motion, or anterior bone-bridging at the second and third cervical levels.

Type-II Injuries

Twenty-nine of these thirty-two patients had a Type-II injury and three had the Type-IIa variation, which will be discussed separately. The initial displacement of the Type-II injuries consisted of a mean of 11.3 degrees of angulation (range, zero to 25 degrees) and five millimeters of translation (range, three to twelve millimeters). Four of the twenty-nine patients were initially treated with a Philadelphia cervical collar for an average of 74.3 days. Three

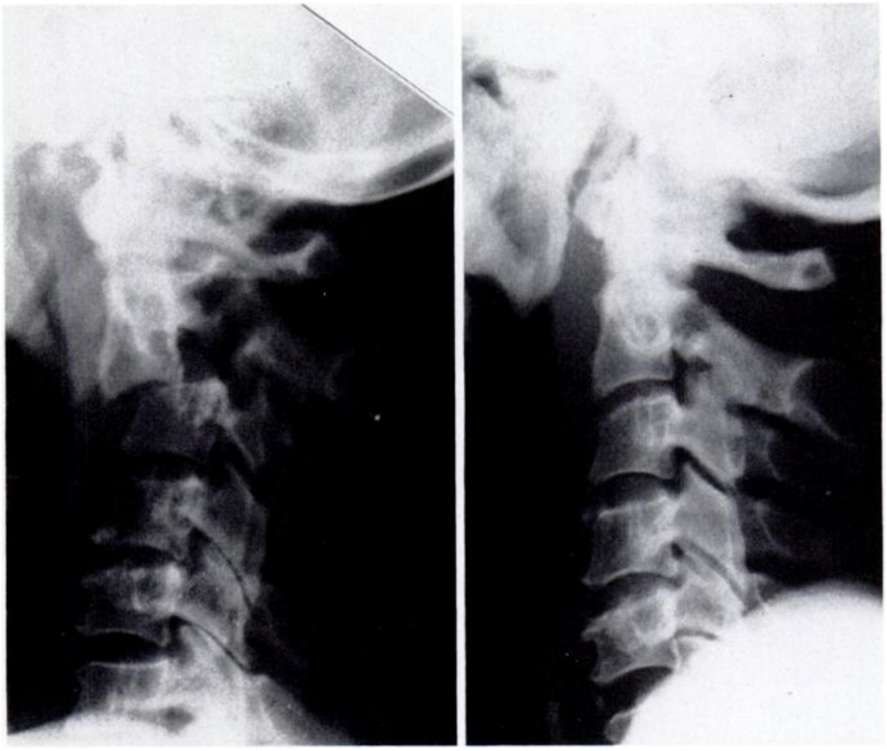

FIG. 7-A FIG. 7-B

Figs. 7-A and 7-B: This patient was admitted with a severely angulated Type-II fracture.
Fig. 7-A: Initial radiograph.
Fig. 7-B: Reduction was achieved with 9.1 kilograms of halo traction without widening of the disc space.

patients died from unrelated injuries before they could be treated. The remaining twenty-two patients were initially immobilized in 6.8 to 9.1 kilograms of halo traction for an average of 7.25 days (range, three to ten days). They were then placed in a halo vest for an average of 85.5 days (range, sixty-eight to 131 days). In nineteen of the twenty-two patients some reduction was achieved with the halo traction, but after reduction there was an average residual translation of 1.8 millimeters (range, zero to five millimeters) and an average residual angulation of 3.8 degrees (range, zero to 10 degrees). No matter how severe the initial deformity, the traction did not cause widening of the disc space (Figs. 7-A and 7-B).

Sixteen of the twenty-two patients with a Type-II fracture who were treated in a halo vest failed to maintain the degree of reduction that had been initially achieved by traction. The residual deformity after the completion of treatment averaged three millimeters of translation (range, zero to seven millimeters) and 4.5 degrees of angulation (range, zero to 11 degrees). Two of the four patients who had been initially treated in a cervical collar had an increase in the fracture deformity during treatment. In one patient who was removed from the halo vest after only two months, the reduction was lost.

The twenty-six surviving patients all had clinical and radiographic union of the fracture in an average of twelve weeks (range, nine to fourteen weeks). Seventeen also had anterior osseous bridging of the second and third cervical vertebrae on follow-up. Although traction achieved a 65 per cent reduction of both angulation and translation, the final residual deformity amounted to 60 per cent of the initial translation and 40 per cent of the initial angulation. This loss in reduction occurred in the halo vest.

Three patients had what we have named a Type-IIa injury (Fig. 8-A). There was no difference in the demographic characteristics of these patients as compared with the rest of the patients with a Type-II injury. In all three of these patients, however, the application of halo traction caused immediate widening of the posterior portion of the disc space between the second and third cervical vertebrae (Fig. 8-B). The traction was immediately removed and reduction was achieved by applying mild compression-extension in a halo vest under fluoroscopic control (Fig. 8-C). The initial angulation was 21 degrees and the translation was 1.3 millimeters. All of these patients went on to bone union, with a final average displacement of 1 degree of angulation and two millimeters of translation.

Type-III Injuries

The five Type-III fractures had an average angulation of 15.6 degrees (range, 8 to 25 degrees) and translation averaging 10.4 millimeters (range, two to thirteen millimeters). All of the Type-III injuries were initially reduced in halo traction, which was maintained for an average of 7.2 days (range, two to eleven days). Two patients were subsequently placed in a halo vest for an average of 106 days, with successful maintenance of the reduction. The remaining three patients required surgical stabilization be-

FIG. 8-A FIG. 8-B FIG. 8-C

Figs. 8-A, 8-B, and 8-C: This patient had Type-IIa traumatic spondylolisthesis.
Fig. 8-A: It was minimally displaced originally.
Fig. 8-B: Traction of 9.1 kilograms caused marked widening of the disc space posteriorly.
Fig. 8-C: The traction was removed and the patient was placed in a halo vest. A good reduction was obtained.

cause of inability to obtain a reduction of the facet dislocation or inability to maintain the reduction of the facet dislocation in a halo vest. In the Type-III fractures in which a bipedicle fracture was anterior to the bilateral facet dislocation, the facets of the second cervical vertebra were free-floating and closed reduction was not always possible. In these patients, an open reduction of the bilateral or unilateral facet dislocation was performed, and a fusion of the second and third cervical vertebrae was done to stabilize the facets. The bilateral pedicle fracture was then treated in a halo vest. In a Type-III fracture in which the fracture line passed either through the facets of the second cervical vertebra or just posterior to the facet dislocation, sometimes the fracture was exceedingly unstable and the reduction of the facet dislocation could not be maintained. In such a situation, bilateral oblique wiring was used to stabilize the dislocation as well as the fracture. The average final residual deformity of the entire group was 9.4 degrees of angulation (range, zero to 15 degrees) and 3.8 millimeters of residual displacement (range, zero to six millimeters). The fractures that had surgical stabilization maintained reduction better than those that were immobilized in a halo vest. All patients in this group showed significant neurological improvement after reduction of the facet dislocation, and no patient sustained a further neurological deficit during the treatment. All of the Type-III fractures united in less than four months, and at follow-up the patients were free of pain with motion, although all had some weather-related symptoms.

In neither Type-II, Type-IIa, nor Type-III lesions did the amount of displacement in any way appear to influence the duration to clinical and radiographic union. In addition, no patient had a residual deformity that was worse than the initial pre-treatment deformity. Although weather-related symptoms were common in most patients during the first twelve months after injury, they usually subsided after that. Restriction of range of motion was not present in flexion, bending, or rotation unless the traumatic spondylolisthesis was accompanied by a second fracture involving the articular surfaces of the first and second cervical vertebrae. This lack of symptoms is almost certainly related to the high incidence of anterior osseous bridging of the second and third cervical vertebrae. In addition, spontaneous fusion of the facet joints was noted in four patients with a Type-II injury after at least thirty-six months of follow-up.

Discussion

The radiographic patterns of injury suggest a correlation between the type of fracture and the mechanism of injury[2,3,5]. Type-I injuries probably result from a hyperextension-axial loading force that fractures the neural arch posteriorly but is not strong enough to disrupt the intervertebral disc or seriously compromise the integrity of the anterior or posterior ligaments. Since there is little laxity in the restraining ligament structures, there is minimum anterior displacement and the fracture is stable. There is also minimum disruption of the anterior portion of the body of the third cervical vertebra. In addition, there is a high association with other hyperextension-axial loading injuries of the cervical spine, such as fractures of the posterior arch and of the atlas, Jefferson fractures, fractures of the lateral mass of the atlas, and certain odontoid fractures.

We think that the Type-II injuries, however, are probably the result of a combined mechanism of injury, in contradistinction to the pure hyperextension-axial loading that has been suggested by other authors[2-5]. These injuries result from an initial hyperextension-axial loading force (as in the Type-I injury) that fractures the neural arch or lamina but causes no more than slight injury to the anterior longitudinal ligament, disc, or posterior capsular structures. Since many of these injuries are caused by vehicular trauma, which may result in both acceleration and deceleration forces in opposite directions, the second force causing the Type-II injury is anterior flexion and compression. The initial fracture through the neural arch allows the entire unit of the head, the atlas, and the body of the second cervical vertebra to displace anteriorly and caudally, separating that unit from the posterior portion of the second cervical vertebra and the remainder of the cervical spine. This component of the injury causes rupture of the posterior longitudinal ligament and the disc from posterior to anterior, which frequently results in compression of the anterosuperior portion of the body of the third cervical vertebra, as seen in twenty-two of the twenty-nine Type-II injuries. Although the flexion-compression force may be severe enough to avulse a portion of the anterior longitudinal ligament from the body of the third cervical vertebra, this does not result in its rupture. This is confirmed by the fact that traction of as much as 6.8 to 9.1 kilograms did not cause abnormal widening of the disc space in any patient with a Type-II injury. The widening of the posterior portion of the disc space in the patients with a Type-IIa injury resulted from a totally different mechanism.

This proposed mechanism of hyperextension-axial loading followed by flexion is compatible with the head-body dynamics that have been noted during certain vehicular accidents, but does not concur with the pure hyperextension-axial loading mechanisms that have been postulated by others[2-5]. Moreover, if the disc and anterior longitudinal ligament had ruptured and subsequent instability resulted from only continued hyperextension and axial loading, then traction with extension over a roll during a reduction maneuver should have yielded abnormal widening of the anterior portion of the disc space in all displaced Type-II injuries, which did not happen. Also, if the mechanism of injury was only hyperextension and axial loading until the anterior longitudinal ligament ruptured, one would expect some avulsion fractures from the anterior portion of the second or third cervical vertebra. However, only one patient in our series had an avulsion fracture, and this was probably the result of anterior stripping of the longitudinal ligament with continued flexion of the neck.

As the mechanism of extension-loading followed by flexion would suggest, there were also significant injuries of either the anterior or superior portion of the body of the third cervical vertebra in most of the patients with a Type-II injury. If the mechanism of injury had been primarily hyperextension and axial loading without a significant flexion force, this compression fracture would not have occurred. Moreover, if the disc and anterior longitudinal ligament had completely ruptured prior to this anterior avulsion fracture, one would suspect that the resultant vertebral displacement might have been sufficient to cause neurological deficit in more patients. Indeed, this might be the case in patients who do not survive as a result of second cervical-level paraplegia secondary to complete dislocation. Instead, there were no neurological deficits in the Type-II group and traction and extension of the neck resulted in accurate reduction, with the anterior longitudinal ligament serving as a checkrein to maintain the proper alignment and relationship of the bodies of the second and third cervical vertebrae.

In the mechanism of injury of both the Type-IIa and Type-III injuries, the predominant force is in flexion and therefore the direction and location of the fractures in these types may be similar. In the Type-I and II injuries the fracture line in the neural arch is predominantly longitudinal and runs through the junction of the pedicle and the body or through the more anterior portions of the neural arch. In the Type-IIa injuries the fractures are more oblique and are located just anterior to the facet joints. In the Type-III injuries the fracture line may be in two locations: (1) oblique, running from anteroposterior to posteroinferior, just posterior to the inferior facet joints — in fact, these are fractures through the bone of the lamina rather than neural arch fractures; or (2) anterior to the facet dislocation in the neural arch. Fracture lines occurring from hyperextension and axial loading would be more probably longitudinal and more anterior in the ring of the second cervical vertebra. For the Type-IIa lesions, the injury patterns can be explained by a flexion-distraction mechanism. In the Type-III injuries, an acute flexion injury results in not only the fracture of the lamina or the pedicle but also bilateral facet dislocation. Thus, in considering the four types of fractures — Types I, II, IIa, and III — we can postulate a sequence of mechanisms, starting first with the pure hyperextension-axial loading in the Type-I fracture, combination hyperextension-axial loading with secondary flexion-compression in Type II, flexion-distraction injury in Type IIa, and finally flexion-compression injury in Type III.

Knowledge of the mechanism of injury can be very helpful in determining the best method of treatment for each of the four types. As Type-I injuries are stable, protection in a cervical collar is probably sufficient. Type-II injuries are certainly unstable, and although the fracture of the neural arch results from hyperextension and axial loading, the displacement of the fracture is the result of flexion and compression. Therefore, an anatomical reduction can be achieved by using a force directly opposite to that which has created the displacement; these fractures can be treated and reduced with approximately seven to nine kilograms of cervical-tong traction, with a roll placed beneath the neck at approximately the level of the fourth and fifth cervical vertebrae to allow distraction and slight hyperextension of the upper part of the cervical spine. Within twenty-four to forty-eight hours an anatomical reduction can usually be achieved. Patients who have less than four or five millimeters of displacement and 10 to 15 degrees of angulation may be able to be mobilized in a halo vest without significant loss of position within seven to ten days. This is evaluated by removing the traction weight from the halo and leaving the patient supine. If no displacement is seen on radiographs made after one hour out of traction, the injury is stable enough for the patient to be transferred into a halo jacket and mobilized. Patients who have significant displacement after the removal of traction at seven to ten days can be returned to traction for approximately six more weeks of immobilization in anatomical alignment. Fracture callus is usually evident by five to six weeks. The patient then wears a halo vest for an additional six weeks. In our experience, early transfer to the halo vest does not maintain reduction in this unstable Type-II fracture, as the device cannot supply enough distraction force to maintain reduction. Although we have been able to maintain sufficient hyperextension, we have not found the halo vest to be capable of maintaining significant distraction. However, even if the reduction is partially lost with early halo-vest immobilization, union is not delayed. Moreover, our patients with even moderate residual displacement had a satisfactory clinical result at follow-up. Residual displacement does not jeopardize the function of the spinal cord, since it results in a larger rather than a smaller neural canal. One might therefore be justified in accepting some residual displacement in the initially less severely-displaced Type-II injuries (less than four millimeters), and we may be able to achieve a satisfactory clinical result with collar immobilization. We are currently comparing the results of collar immobilization and those of halo immobilization in a prospective study.

Type-IIa injuries probably result from flexion-distraction forces. Since initially these lesions were not recognized to be different from any other severely displaced Type-II fracture, the patients were all placed in a halo vest using 6.8 to 9.1 kilograms of traction. Immediately the fractures became even more severe. They appeared to hinge off from the anterior longitudinal ligament, which had not been avulsed from the body of the second cervical vertebra. When we saw this increase in angulation, in each patient we then recognized that this was not merely a severely angulated Type-II fracture. When the Type-IIa pattern was recognized, the patient was removed from traction and placed in a halo vest. This injury is best reduced by using a mechanism opposite to that of the mechanism of injury; that is, by compression and slight extension of the neck. This can be achieved adequately by primary application of a halo vest and reduction under image-intensifier control using manual compression and slight extension of the neck.

Type-III injuries are very unstable and are best treated initially by the immediate application of halo traction for reduction of the facet-dislocation component. Since there are several possible configurations of this injury (unilateral or bilateral facet dislocation and pedicle or laminar fracture), the treatment options vary. However, reduction of the facet dislocation is of primary importance. In the patient with a unilateral or bilateral facet dislocation and a true pedicle fracture, the inferior facet of the second cervical vertebra is free-floating and closed reduction is usually not possible. Immediate open reduction is often necessary, and we suggest stabilization and fusion of the dislocation followed by treatment of the bipedicle fracture with external immobilization. When the facet dislocation is associated with a fracture of the neural arch at the level of the facets or just posterior to them, closed reduction is usually possible. As there is loss not only of the osseous integrity of the lamina of the second cervical vertebra, but also of the combination of the capsular ligaments of the facet joint, these fractures were difficult to hold in accurate reduction in either halo traction or a halo vest. Hence, we recommend that this kind of Type-III fracture-dislocation be treated as are other bilateral facet dislocations in the cervical spine[9], with posterior fixation and fusion of the second and third cervical vertebrae. Although some authors[1] have advocated anterior fusion, an anterior approach would compromise the only residual stabilizing structure (the anterior longitudinal ligament) and does not directly address the bilateral facet dislocation. We therefore recommend a posterior approach. In most bilateral facet dislocations the spinous processes of the two levels are intact and a simple one-level interspinous wiring can be performed to give immediate stability to the injury. However, in the Type-III axial injury the spinous process of the second cervical vertebra remains attached to the third cervical vertebra and the bilateral laminar fracture allows the facet dislocation to occur. We therefore suggest bilateral oblique wiring from the second to the third cervical vertebra; this gives immediate stability and allows a one-level fusion to occur.

Therefore, our classification provides a continuum of mechanisms that are all interrelated. By understanding these mechanisms of injury, a logical and effective treatment program can be established for patients with traumatic spondylolisthesis of the axis.

References

1. Böhler, J.: Personal communication.
2. Brashear, H. R., Jr.; Venters, G. C.; and Preston, E. T.: Fractures of the Neural Arch of the Axis. A Report of Twenty-nine Cases. J. Bone and Joint Surg., **57-A:** 879-887, Oct. 1975.
3. Cornish, B. L.: Traumatic Spondylolisthesis of the Axis. J. Bone and Joint Surg., **50-B(2):** 31-43, 1968.
4. DeLorme, T. L.: Axis Pedicle Fractures. *In* Proceedings of The American Orthopaedic Association. J. Bone and Joint Surg., **49-A:** 1471, Oct. 1967.
5. Effendi, B.; Roy, D.; Cornish, B.; Dussault, R. G.; and Laurin, C. A.: Fractures of the Ring of the Axis. A Classification Based on the Analysis of 131 Cases. J. Bone and Joint Surg., **63-B(3):** 319-327, 1981.
6. Francis, W. R.; Fielding, J. W.; Hawkins, R. J.; Pepin, John; and Hensinger, Robert: Traumatic Spondylolisthesis of the Axis. J. Bone and Joint Surg., **63-B(3):** 313-318, 1981.

7. GROGONO, B. J. S.: Injuries of the Atlas and Axis. J. Bone and Joint Surg., **36-B(3):** 397-410, 1954.
8. HAUGHTON, S.: On Hanging, Considered from a Mechanical and Physiological Point of View. London, Edinburgh and Dublin Philos. Mag. and J. Sci., **32:** 23-34, 1866.
9. ROGERS, W. A.: Fractures and Dislocations of the Cervical Spine. An End-Result Study. J. Bone and Joint Surg., **39-A:** 341-376, April 1957.
10. SCHNEIDER, R. C.; LIVINGSTON, K. E.; CAVE, A. J. E.; and HAMILTON, GILBERT: "Hangman's Fracture" of the Cervical Spine. J. Neurosurg., **22:** 141-154, 1965.
11. TERMANSEN, N. B.: Hangman's Fracture. Acta Orthop. Scandinavica, **45:** 529-539, 1974.
12. WHITE, A. A., III, and PANJABI, M. M.: Clinical Biomechanics of the Spine. Philadelphia, J. B. Lippincott, 1978.
13. WOOD JONES, FREDERIC: The Examination of the Bodies of 100 Men Executed in Nubia in Roman Times. British Med. J., **1:** 736-737, 1908.
14. WOOD-JONES, FREDERIC: The Ideal Lesion Produced by Judicial Hanging. Lancet, **1:** 53, 1913.

Intercondylar Fractures of the Humerus

AN OPERATIVE APPROACH*

BY JESSE B. JUPITER, M.D.†, URS NEFF, M.D.‡, PETER HOLZACH, M.D.‡, AND MARTIN ALLGÖWER, M.D.‡, BASLE, SWITZERLAND

From Kantonsspital, Basle

ABSTRACT: **In this paper we review a series of thirty-four intercondylar fractures of the distal end of the humerus that were treated by open reduction over a ten-year period. The fracture patterns were classified according to the system of Müller et al. and a strict rating scale incorporating subjective data, objective motion, and the functional status of the involved elbow was used for the results. At a mean follow-up of 5.8 years, thirteen results were rated as excellent; fourteen, as good; four, as fair; and three, as poor. Complications included post-operative neuritis in five patients; three non-unions; and refracture, heterotopic bone, and deep sepsis in one patient each.**

Since the original description by Desault in 1811, the intercondylar fracture of the distal end of the humerus has remained one of the most difficult of all fractures to manage. Recommendations for treatment have ranged widely, from essentially no treatment to operative reduction and extensive internal fixation[2-4,7,11,13,14,19,20,23]. The problem of management has been made more difficult by the fact that the fracture is relatively uncommon, which prevents the individual surgeon from accumulating sufficient personal experience to critically evaluate the results of treatment.

In some of these fractures, particularly those with intra-articular comminution, anatomical restoration of the articular surface cannot be adequately achieved or maintained through manipulative reduction alone. Critics of open reduction have argued that the additional surgical trauma and the inherent difficulty in securely stabilizing the small intra-articular fragments will lead to added fibrosis and a less satisfactory result[7,23]. Even authors who have recommended open reduction differed widely in their opinions with regard to the extent and type of internal fixation to be used, as well

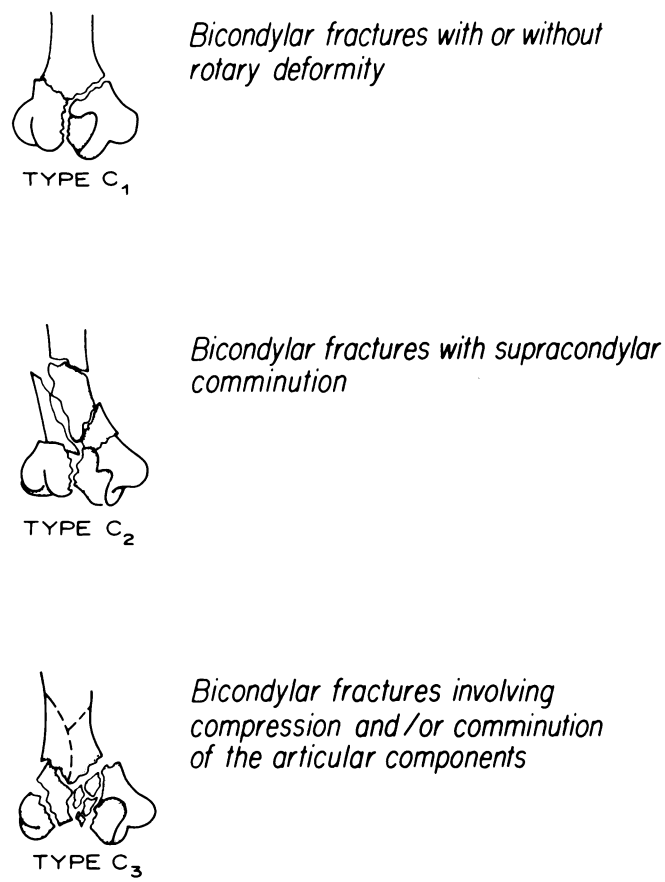

FIG. 1

The system of Müller et al., used for classification of intercondylar fractures of the distal end of the humerus.

* Read in part at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Atlanta, Georgia, February 9, 1984.

† Department of Orthopaedic Surgery, ACC 427, Massachusetts General Hospital, Boston, Massachusetts 02114.

‡ Department of Surgery, University Hospital, CH-4031, Basle, Switzerland.