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Bivector Traction for Unstable Cervical Spine Fractures: A Description of Its Application and Preliminary Results

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Summary: The management of acute, displaced odontoid fractures requires the restoration of sagittal alignment and rigid external or internal immobilization to prevent late instability and achieve union. This report introduces a new traction technique for the reduction of posteriorly displaced type 2 odontoid fractures. Seven patients with traumatic injuries to the dens were placed in bivector traction for an awake closed reduction. Sagittal alignment was restored and maintained in all patients with no neurologic deterioration or traction-related complications during an average of 11 days (range, 2–28 days) in traction. The overall sagittal alignment corrected from an initial average of 12.2 mm (range, 5–22 mm) of posterior displacement to an average of 1.1 mm (range, 0–3 mm) at the completion of reduction. Only one patient had residual angulation, which measured 5°. Three patients achieved an osseous union and the remaining four required a posterior C1–C2 fusion for nonunion. Although operative stabilization may be the preferred approach in this patient population and injury pattern, we conclude that bivector traction is a safe and effective technique for the initial management of posteriorly displaced odontoid fractures. In addition, its role can be expanded to the closed reduction of lower cervical spine fractures in patients with fixed flexion deformities secondary to ankylosing spondylitis or disseminated intraosseous segmental hyperostosis. **Key Words:** Odontoid fracture, reduction—Traction—Ankylosing spondylitis—Cervical fracture.

According to the classification system introduced by Anderson and D'Alonzo in 1974 (1), a type 2 fracture occurs at the junction of the odontoid process and the body of C2. Management of a type 2 fracture is complicated by a significant nonunion rate when treated nonoperatively. Clinical and radiographic factors that correlate with this high rate of nonunion include the patient's age and degree or direction of fracture displacement.

Unstable type 2 odontoid fractures often have significant posterior displacement (2). Closed reduction of these fractures must take into consideration both axial and posterior deforming forces. Axial tong traction or halo manipulation have been used traditionally with varied success in achieving and maintaining fracture reduction. Furthermore, collars or braces should not be used as a primary treatment in most instances, because of the unacceptable nonunion rate and their lack of immobilization of the upper cervical spine. Bivector traction was initially developed for the acute reduction of this subtype of odontoid fractures. This system provides the essential vectors required to restore the sagittal alignment at the C1–C2 junction. Since its introduction, it has subsequently been used in the management of lower cervical spine injuries complicated by ankylosing spondylitis and coexisting flexion deformities of the cervical spine.

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The purpose of this study is to illustrate the technique of bivector traction for the initial management of unstable cervical spine fractures where both vertical and horizontal reduction vectors are required. This technique has successfully been used to acutely manage two groups of patients: (a) acute type 2 odontoid fractures with posterior displacement and angulation, and (b) acute cervical spine fractures in patients with preinjury flexion deformities secondary to ankylosing spondylitis or disseminated idiopathic skeletal hyperostosis.

MATERIALS AND METHODS

We retrospectively reviewed seven consecutive patients with a traumatic type 2 odontoid fracture treated with bivector cervical traction who were admitted to Thomas Jefferson University Hospital, the Regional Spinal Cord Injury Center of the Delaware Valley, between April 1992 and February 1993. There were five male and two female patients with an age range of 68–89 years (mean, 77 years).

We recorded the mechanism of injury, presenting neurologic status, associated injuries, weight required for reduction, location of traction vectors, duration of traction, and traction-related complications. Radiographic evaluation included a complete spine series on presentation and serial lateral cervical spine radiographs during the reduction. Computerized tomography was routinely used to delineate the fracture pattern and degree of comminution.

The degree of fracture angulation and amount of posterior displacement were recorded from the injury and postreduction radiographs (Table 1). We measured fracture angulation as the angle between the vertical axis of the proximally displaced dens fragment and a line parallel to the posterior body of the axis. Fracture displacement was defined as the horizontal distance from the posteroinferior margin of the proximally displaced dens fragment and the posterosuperior margin of the C2 body (Fig. 1).

Bivector Traction Technique

Patients admitted to our institution with posteriorly displaced type 2 odontoid fractures are managed initially with bivector cervical traction following the guidelines established by the senior author (J.M.C.). Following standard resuscitative protocols, magnetic resonance imaging–compatible cranial tongs or an open-back halo ring is placed using standard insertion techniques. The advantage of the open-back halo ring is to allow rapid convergence to the halo-vest system after fracture reduction. Patients are then transferred to a Rotorest (Kinetic Concepts, Austin, TX, U.S.A.) continuous motion bed.

The goal of the bivector traction system is to establish two vector forces, an anterior and superior vector, which create a resultant force that distracts and anteriorly translates the posteriorly displaced proximal fragment. The vector forces are applied using graduated weights and a mobile pulley system.

The superior axial vector provides distraction through the application of weights to a traction bail fixed to the halo ring or metal "S" hook if tongs are used. The anterior vector force translates the posteriorly displaced ring of C1 and proximal odontoid fragment while providing a flex-

TABLE 1. *Summary of patient demographics and vector force of reduction and maintenance*

	Presentation				Reduction				Maintenance		
Age (yrs)	MOI[a]	A/P (mm)[b]	Fx (deg)[c]	C1[d]	Sup (lbs)[e]	Ant (lbs)[f]	A/P (mm)[g]	Fx (deg)[h]	Sup (lbs)[i]	Ant (lbs)[j]	Dur. (days)[k]
80	Fall	15	5	No	25	25	1	0	10	20	2
72	Fall	0	15	Yes	15	15	3	0	14	13	18
86	Fall	12	0	Yes	15	20	3	5	15	20	2
89	Fall	5	5	No	15	15	0	0	10	15	7
68	Fall	1	5	No	25	15	0	0	10	10	28
71	Fall	11	10	Yes	35	15	1	0	5	5	16
78	Fall	22	30	No	10	5	0	5	10	5	4
Avg.											
77	·	12.1	7.3		17.9	15.7	1.1	0.7	10.6	12.6	10.8

[a]Mechanism of injury.
[b]Anterior–posterior displacement on presentation in millimeters.
[c]Fracture angle on presentation in degrees.
[d]Concomitant C1 fracture on presentation.
[e]Superior reduction vector force in pounds.
[f]Anterior reduction vector force in pounds.
[g]Anterior–posterior displacement after reduction in millimeters.
[h]Fracture angle after reduction in degrees.
[i]Final maintenance superior vector force in pounds.
[j]Final maintenance anterior vector force in pounds.
[k]Duration of traction in days.

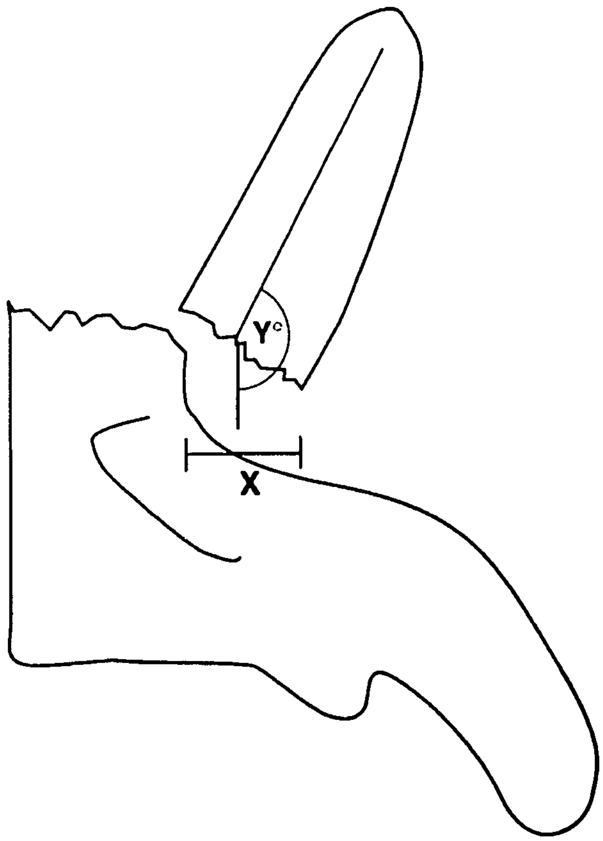


FIG. 1. Fracture displacement was measured as the horizontal distance from the posterior inferior margin of the proximally displaced dens fragment and the posterior superior margin of the C2 body in millimeters (x). Fracture angulation (Y) was measured as the angle between the vertical axis of the proximally displaced dens fragment and a line parallel to the posterior body of the axis.

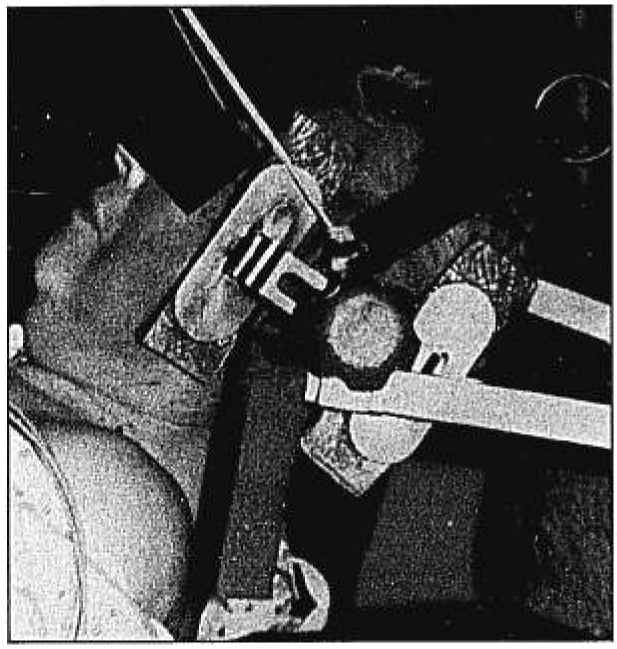


FIG. 2. Bivector traction apparatus using a magnetic resonance imaging–compatible tong. Superior traction weights are attached directly to the "S" ring at the apex of the tong. The anterior vector force is applied by connecting the weight through a cord attachment to the midpoint of a cord connecting both tong insertion pins.

ion moment to correct fracture angulation. This is accomplished through a cord attached to the anterior aspect of the halo ring or to both tong insertion pins (Fig. 2) and passed through the pulley to the foot of the bed. The mobile pulley system allows the direction of the vector forces to be modified during the reduction.

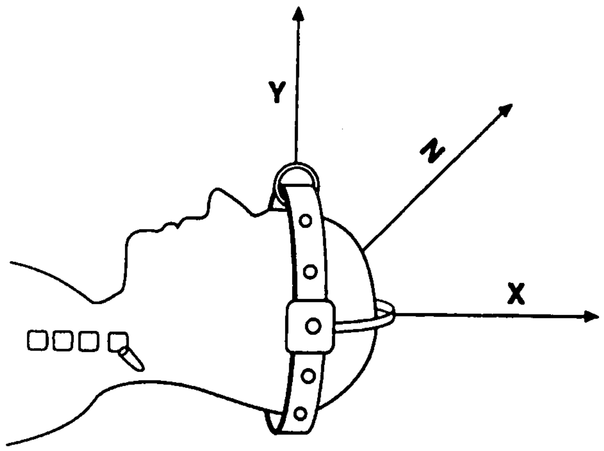
The two vector forces are initially applied perpendicular to each other (Fig. 3), and using serial roentgenographs and careful neurologic monitoring a closed reduction is attempted through the gradual application of weight to both pulley systems. Initially, 5 lb are placed on each pulley, and a lateral radiograph is reviewed. The addition of weight in increments of 1–2 lb and altering the position of the pulleys are routinely performed until the desired reduction is achieved. This allows careful titration of the reduction forces with close radiologic and neurologic scrutiny.

Once an acceptable reduction is confirmed radiographically, bed rotation is permitted. Daily lateral cervical spine roentgenographs are obtained to monitor fracture alignment. The patient's head is routinely suspended off the bed because of the anterior vector force required for reduction.

RESULTS

The mechanism of injury in all seven patients was a fall from the standing position. Three patients had concomitant C1 ring fractures. The initial posterior displacement ranged from 5 to 22 mm, with an average of 12.2 mm. Fracture angulation on prereduction radiographs ranged from 0 to 30°, with an average of 7.3°. At the completion of reduction, the average posterior displacement was 1.1 mm, with a range of 0–3 mm. Only one patient had residual fracture angulation measuring 5°. Fracture alignment was maintained in all patients once the reduction was achieved. The traction period averaged ~10.8 days, with a range of 2 days–4 weeks. The duration of bivector traction was determined by the senior author (J.M.C.) and was predicated on the degree of fracture comminution.

The amount of weight required to achieve reduction averaged 17.9 lb (range, 10–35 lb) at the superior pulley and 15.7 lb (range, 5–25 lb) at the anterior pulley. The amount of weight required to maintain the reduction averaged 10.6 lb (range, 5–15 lb) at the superior pulley and 12.6 lb (range, 5–20 lb) at the anterior pulley. The neurologic status of all seven patients remained unchanged from



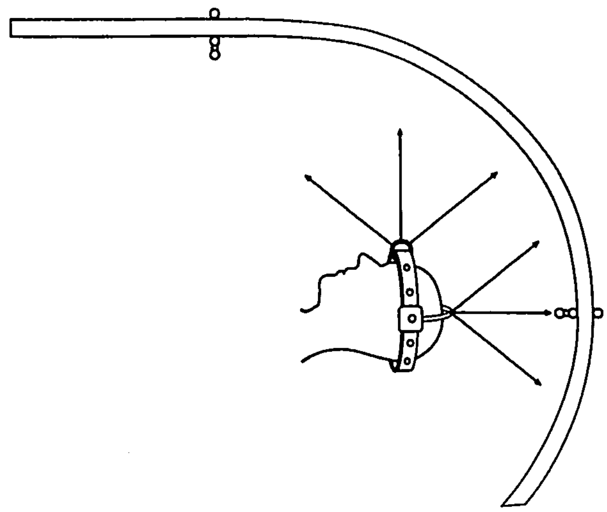


FIG. 4. Schematic representation of vector force options available with the bivector arc system.

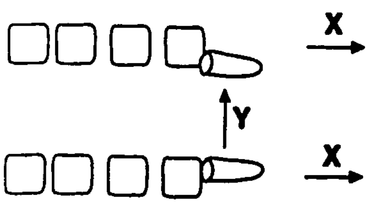


FIG. 3. Schematic representation of anterior and superior vector forces required to reduce a posterior displaced odontoid fracture.

admission, and no traction-related complications were encountered.

All of the patients were safely converted to a custom-made halo vest without compromising the fracture reduction. This device requires frequent monitoring to prevent skin breakdown and late fracture displacement. Although the length of hospitalization and number of device-related adjustments were not recorded, this population of patients routinely required extended care facilities where prevention of halo-vest complications was possible.

DISCUSSION

Type 2 odontoid fractures are typically associated with a hyperextension or hyperflexion mechanism of injury (3). An unstable fracture pattern is identified radiographically by the degree of posterior displacement and angulation. Postmortem findings on patients with upper cervical spine injuries at the time of death revealed an intact transverse ligament in patients with type 2 odontoid fractures (5). These data suggest that an intact transverse ligament imparts a posterior shearing force to the anterior dens, contributing to the posterior displacement observed in hyperextension injury patterns. Therefore, the use of standard traction techniques to restore the sagittal alignment of the C1–C2 junction in this injury pattern would fail to adequately address the deforming forces. This prompted our senior author (J.M.C.) to investigate bivector traction as a means of obtaining fracture reduction without compromising neurologic function.

In our series, all patients had radiographic evidence validating a hyperextension mechanism of injury with a range of 5–22 mm of posterior displacement. Bivector traction safely corrected the deforming forces by providing two somewhat perpendicular vectors that in combination minimize the weight required for reduction. For acute reductions, the traction force did not exceed 30 lb, and <15 lb was required to maintain reduction. The friction inherent to a pulley-traction system and the inertia of the patient's head may provide biomechanical limitations to this technique. However, to compensate for this, we routinely administer low-dose intravenous narcotics or muscle relaxants to counteract the cervical paraspinal muscle spasms after acute injuries. In addition, gentle manual elevation of the patient's head by orthopaedic staff members may be required to initiate the force of the traction vectors. This can be technically difficult to apply in a clinical setting, especially in inexperienced hands. Therefore, we recommend its use at institutions equipped to manage acute spinal trauma. To date, no patient has had neurologic deterioration resulting from our traction system or protocol.

Bivector traction has evolved since it was first used at our institution. The need for additional weight anteriorly prompted the development of an overhead traction attachment that allows movement of the pulleys for more effi-

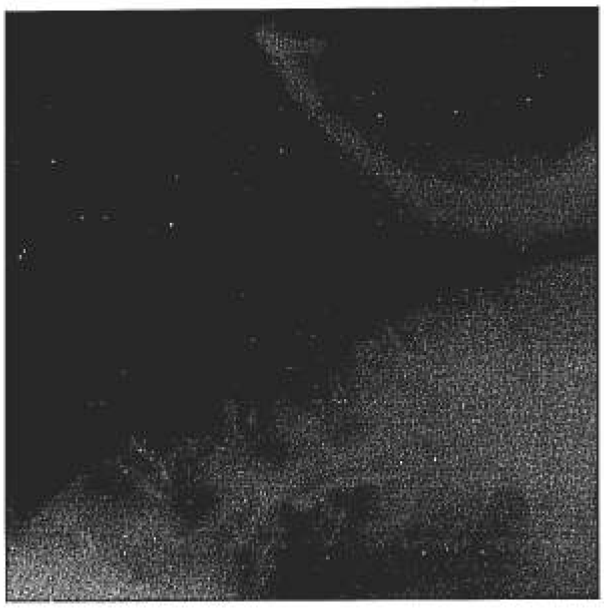


FIG. 5. Cervical fracture in a patient with ankylosing spondylitis. Note the significant anterior force needed to obtain an adequate reduction.

cient flexion moments (Fig. 4). The importance of this system is its ability to gradually and safely titrate the reduction forces through two vector forces. The superior force vector provides axial distraction while the anterior force provides flexion and translation. Although residual displacement and angulation can occur, the resultant reduction uniformly permitted conversion to a custom halo-vest orthosis for patient mobilization.

Another subset of patients in which bivector traction may prove useful is in lower cervical spine injuries complicated by preinjury flexion deformities characteristic of patients with ankylosing spondylitis (Fig. 5). These patients are at an increased risk for developing fractures of the cervical spine (4) and present as a management problem in the acute setting. We have recently used bivector traction in this population for the acute reduction of lower cervical spine injuries. We have noted good success in restoring the sagittal alignment of the lower cervical spine while maintaining the patient's inherent flexed posture and neurologic status.

Although the patients in our study satisfy the criteria of many investigators for operative stabilization, we maintain that bivector traction when used in the acute setting is a safe and effective means of reducing unstable and potentially catastrophic cervical spine fractures.

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