Acute axis fractures: a review of 229 cases

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Eighteen percent of acute cervical spine fractures involve the C-2 vertebra. The odontoid Type II fracture is the most common axis fracture and it is also the most difficult to treat. The degree of odontoid dislocation has been identified as the single most important fracture feature that helps separate those patients who have a high likelihood of healing with nonoperative therapy from those who are likely to fail nonoperative therapy and should be offered early surgical stabilization. The difference is statistically significant (p < 0.001, $\chi^2 = 30.20$).

The present series includes 229 patients with acute axis fractures. Follow-up data were available in 92% of these patients, for a median duration of 4 years 9 months. Treatment guidelines and results are offered for each subtype of axis fracture based on this experience.

KEY WORDS: axis fracture • cervical spine • odontoid fracture • spinal fracture

TREATMENT of C-2 vertebral (axis) fractures has evolved over the last 10 years.$^{2,4,9,11-13,17,23,25,29}$ New fracture types have been identified, and nonodontoid, nonhangman’s C-2 fractures have been classified.$^{14,15,17,28,29}$ Treatment of the most common type of axis fractures, odontoid Type II fractures, remains controversial. Investigators have attempted to identify specific patient or fracture features that might guide appropriate therapy.$^{2,4,9,11-13,17}$ The degree of dens dislocation has been cited as the single most important factor that determines the success or failure of nonoperative treatment of odontoid Type II fractures.$^{9,13,17,29}$

Several authors maintain that patient age is an important consideration when deciding between operative and nonoperative therapy.$^{4,11,12}$ In this review, we outline our approach to the treatment of 229 consecutive acute axis fractures and offer specific recommendations regarding the management of patients with odontoid Type II fractures.

Clinical Material and Methods

This review involves 229 acute axis fractures treated by the Spinal Cord Injury Service at Barrow Neurological Institute between 1976 and 1987. Patients with congenital anomalies of C-1 or C-2, those with rheumatoid arthritis or neoplastic involvement of C-2, or those with missile injuries of the axis were excluded from the series. The medical records and roentgenograms of these 229 patients were reviewed in detail. Follow-up data were available for 211 (92%) of the cases, for a median duration of 4 years 9 months (range 1 month to 8 years). Follow-up studies consisted of repeat examination and lateral radiographs including flexion and extension views. Statistical comparisons were made using standard chi-square analysis methods.

Results

Odontoid fractures were the most common C-2 fracture types, encountered in 136 cases (60% of the total, Table 1). There were no odontoid Type I fractures in this series; 87 patients had odontoid Type II fractures and 49 had odontoid Type III fractures. There were 46 hangman’s fractures and 47 miscellaneous axis fractures (nonodontoid nonhangman’s fractures), each representing 20% of the acute axis fracture population. In this patient group, males outnumbered females by 2:1; the median age by sex was 37 years for males (range 10 to 94 years) and 41 years for females (range 2 months to 90 years). The most common causes of injury were motor-vehicle accidents (65%), followed by falls (15%) and diving injuries (6%); miscellaneous accidents comprised 14% of axis fractures. The 229 axis fractures represented 18% of all acute cervical spine fractures managed at this institution (1280 cervical spine fractures) over the 12-year period of the study (January, 1976, to January, 1988).

Thirteen patients with C-2 fractures (5.7%) sustained neurological injury, and 15 patients (6.5%) died. Three
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TABLE 1
Types of axis fractures among 229 patients studied

<table>
<thead>
<tr>
<th>Type of Axis Fracture</th>
<th>Cases No.</th>
<th>Percent</th>
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<tbody>
<tr>
<td>odontoid Type I (apical dens fracture)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>odontoid Type II (base dens fracture)</td>
<td>87*</td>
<td>38</td>
</tr>
<tr>
<td>odontoid Type III (dens fracture into C-2 body)</td>
<td>49</td>
<td>22</td>
</tr>
<tr>
<td>hangman's (bilateral pars interarticularis)</td>
<td>46</td>
<td>20</td>
</tr>
<tr>
<td>miscellaneous (nonhangman's nonodontoid C-2 fracture)</td>
<td>47</td>
<td>20</td>
</tr>
</tbody>
</table>

* Three patients had Type IIA fractures (base dens fractures with multiple bone chips).

Forty-seven patients sustained acute nonodontoid nonhangman's fractures of the axis (Table 2).14 The majority of the fractures involved the vertebral body or lateral mass. Three of these patients died early in their course of treatment.

The treatment of the remaining 44 patients with miscellaneous axis fractures depended upon the type of fracture involved and the degree of associated subluxation (usually at C2–3), when present. One patient with a C-2 lateral mass fracture and a 5-mm subluxation of C-2 on C-3 underwent early surgical therapy consisting of posterior wiring and C1–3 fusion. Thirty-six patients were treated in a halo vest, four in a SOMI brace, and three in a Philadelphia collar for periods of 8 to 17 weeks (median duration 10 weeks). One patient with a C-2 body fracture and an associated 4-mm C2–3 subluxation had instability with nonunion after 15 weeks of halo vest immobilization. She was ultimately treated with a posterior C2–3 wiring and fusion procedure. No other patient had evidence of nonunion or instability at the last examination. The two surgical patients had stability with union at last follow-up review.

Hangman's Fractures

Two of the 46 patients with hangman's fractures of the axis died early in their hospital course (Table 2). Of the remaining 44 patients, 39 were treated with a halo immobilization device and five with a sternoc-occipitomandibular immobilizer (SOMI) brace for periods of 10 to 16 weeks (median duration 11 weeks).

Two patients did not achieve bone union with halo vest immobilization and required surgical stabilization. The first was a 64-year-old woman with marked C2–3 subluxation and distraction. She could not be held in adequate alignment with the halo device and underwent posterior wiring and fusion of C1–3 with autologous iliac crest bone graft fusion on her 5th postinjury day. The other patient was a 35-year-old man with a C-2 level central cord injury from a combination C-1 ring fracture, C-2 hangman's fracture, and C-3 spinous process fracture. He had marked instability and subluxation at C2–3. He could not be immobilized adequately with a halo vest and was treated with an anterior C2–3 discectomy and anterior autologous iliac crest bone graft fusion with Casper plating of C-2 and C-3.

None of the 42 patients treated nonoperatively showed instability at the last follow-up examination. The two patients treated with early surgical therapy had no evidence of nonunion or instability at their last evaluation.

Miscellaneous Axis Fractures

Forty-nine patients presented with acute odontoid Type III fractures (Table 2). All patients but one were treated with nonoperative immobilization (46 in a halo vest and two in a SOMI brace) for a period of 10 to 20 weeks (median 11 weeks). One patient with a marked C2–3 subluxation required early operative reduction and fusion. All patients with Type III fractures were stable with good bone union at the last follow-up examination.

Odontoid Type II Fractures

Eighty-seven patients presented with acute odontoid Type II fractures (Table 2). Three patients died within 1 week from severe head or cardiopulmonary injuries. Six patients with odontoid Type II fracture-dislocations of 6 mm or greater and three with Type II A fractures were treated with early surgery, consisting of C1–2 posterior wiring and fusion procedures. Seventy-five patients were initially treated with nonoperative external immobilization (65 with halo immobilization devices, eight with SOMI braces, and two with Philadelphia collars) for durations of 10 to 23 weeks (median 12 weeks). Excluding nine patients with early surgery, six
patients who died, and four patients lost to follow-up review, 68 patients were available for long-term evaluation.

The nonunion rate for 68 acute odontoid Type II fractures initially treated with nonoperative immobilization-stabilization was 28% (19 patients). This rate is in keeping with those reported in other series. Of these 19 patients, five developed long-term union and stability after a further period of immobilization in a halo vest; two had been initially treated in a Philadelphia collar, two in a halo vest, and one in a SOMI brace. The remaining 14 patients required surgical stabilization and fusion.

Individuals with odontoid Type II fractures in which the dens was dislocated less than 6.0 mm had a 10% nonunion rate compared to a 78% nonunion rate for patients with dens dislocations of 6.0 mm or greater. This difference was true irrespective of the patients' age or neurological condition, or the direction of the dens dislocation; the difference was statistically significant ($p < 0.001$, $x^2 = 30.20$) (Figs. 1 and 2).

**Odontoid Type IIA Fractures**

Three patients presented with acute odontoid Type II fractures with large additional bone chips at the dens fracture site. These injuries have been designated Type IIA fractures. These odontoid fractures could not be reduced or successfully realigned or immobilized in a halo vest. All three patients required early surgical stabilization and fusion.

**Discussion**

Acute traumatic axis fractures are common cervical spine injuries, often sustained in motor-vehicle accidents or falls. Eighteen percent of the cervical spinal column fractures treated at our institution over a 12-year period involved the C-2 vertebra. These fractures occur in patients of all ages (between 2 months and 94 years of age in this series). With the advent of highly specific high-resolution imaging techniques such as computerized tomography (CT), three dimensional CT, and magnetic resonance imaging, axis fractures have been further categorized by individual fracture features: hangman's fractures, miscellaneous fractures, and odontoid fractures Types I, IIA, and III.

It is estimated that as many as 25% to 40% of patients with acute C-2 fractures die at the scene of the accident. Among those who do survive transport to the hospital with acute axis fractures, neurological morbidity is relatively low (3% to 10%) but this varies somewhat depending on the type of acute axis injury present. The majority of axis fractures can be effectively treated with a period of rigid external immobilization, typically 10 to 12 weeks following fracture realignment. The halo vest is favored for most C-2 fracture-dislocations because of its ability to immobilize the head and superior cervical spine with respect to the torso, and the low complication rate associated with proper halo vest use and care.

Specific treatment recommendations based on a large experience with each of the major axis fracture subtypes can be offered (Table 2). In general, hangman's fractures, odontoid Type III fractures, and most miscellaneous axis fractures are effectively managed with nonoperative means (typically, the halo vest with its rigid external immobilization). Whatever form of external

**FIG. 1.** Correlation of dens dislocation, direction of dislocation, and the incidence of nonunion for odontoid Type II fractures in 87 cases.
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FIG. 2. Correlation of dens dislocation, patient age, and the incidence of nonunion for odontoid Type II fractures in 87 cases.

immobilization is employed, frequent follow-up monitoring is required to assure proper alignment and long-term bone union with stability.

Exceptions to the nonoperative rule for these three fracture subtypes may be the patients with a hangman's fracture, odontoid Type III fracture, or miscellaneous axis fracture with a significant C2-3 subluxation. Two patients who underwent early surgery (one with a Type III fracture, the other with a miscellaneous fracture) and three patients who had nonunion when treated in a halo vest and required late surgery (two with a hangman's fracture, the other with a miscellaneous fracture) all had 3- to 6-mm subluxation of C-2 on C-3 complicating their fracture injury. These may be patients to consider for early operative reduction and bone fusion.

Historically, the management of odontoid Type II fractures has been controversial. These injuries are associated with the highest failure rate of all axis fracture subtypes when treated with external immobilization (Table 2), a fact which has led several investigators to advocate early surgical therapy for most of these patients. A number of authors have attempted to define certain patient features (such as patient age or neurological injury) and/or fracture characteristics (such as degree or direction of dens dislocation) which, if present, would help determine optimal therapy in a specific case (Table 3).

In a review of 107 axis fractures, Hadley, et al., compared the nonunion rate of odontoid Type II fractures with each of the patient and fracture characteristics outlined above. Their overall nonunion rate for Type II fractures was 26%. The degree of dens dislocation was the only statistically significant feature that affected the rate of union and stability with external immobilization. Patients with a dens dislocation of less than 6 mm had a nonunion rate of 9% compared to a 67% incidence of nonunion for patients with a dens dislocation of 6 mm or greater, irrespective of patient age.

### TABLE 3
Factors studied in association with nonunion of Type II odontoid fractures

<table>
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<tr>
<th>Authors &amp; Year</th>
<th>Nonunion Rate</th>
<th>Factors</th>
</tr>
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<tbody>
<tr>
<td>Schatzker, et al., 1971</td>
<td>63%</td>
<td>posterior displacement</td>
</tr>
<tr>
<td>Anderson &amp; D’Alonzo, 1974</td>
<td>36%</td>
<td>age &gt; 40 yrs; dislocation &gt; 4 mm</td>
</tr>
<tr>
<td>Apuzzo, et al., 1978</td>
<td>33%</td>
<td>age &gt; 55 yrs; posterior dislocation; dislocation of 4-6 mm</td>
</tr>
<tr>
<td>Ekong, et al., 1981</td>
<td>41%</td>
<td>age &gt; 55 yrs; posterior dislocation; dislocation of 4-6 mm</td>
</tr>
<tr>
<td>Hadley, et al., 1985</td>
<td>26%</td>
<td>dens dislocation ≥ 6 mm, irrespective of direction; age not significant factor</td>
</tr>
<tr>
<td>Clark &amp; White, 1985</td>
<td>25%</td>
<td>age &gt; 65 yrs; degree of neurological deficit; posterior dislocation</td>
</tr>
<tr>
<td>Dunn &amp; Seljeskog, 1986</td>
<td>24%</td>
<td>age &gt; 65 yrs; degree of neurological deficit; posterior dislocation</td>
</tr>
<tr>
<td>Hadley, et al., 1989</td>
<td>28%</td>
<td>dens dislocation ≥ 6 mm, irrespective of direction; age not significant factor</td>
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age, neurological deficit, or the direction of dislocation. These findings agreed with a report by Clark, et al.9

Despite these findings, doubt still remains about the treatment of patients over 60 years of age with a Type II fracture. Many investigators believe that these patients will not heal with external immobilization and should be offered early surgical therapy, irrespective of the degree of dens dislocation.4,11,12,23,25 The present review adds further insight to this issue. Of 68 patients with Type II fractures available for long-term follow-up review who were not offered early surgical therapy but were treated with rigid external immobilization, 33 were 60 years of age or older. Patients aged 60 years or older had a 39% overall nonunion rate compared to 15% for patients aged less than 60 years (p < 0.05, x² = 6.06). These figures are altered somewhat by our previous bias to perform early surgical therapy on younger patients with a 6-mm or greater dens dislocation and a relative reluctance to proceed with early surgical treatment in the more frail, older age group. Compared with younger patients, those aged 60 years or older had a slightly higher incidence of nonunion if the dens was dislocated 6.0 mm or greater (85% vs. 75%; p < 0.6, x² = 6.06) and a higher incidence of nonunion for dens dislocations less than 6.0 mm (13% vs. 7%); however, these differences were not statistically significant. If the nonunion rate for a fracture with a dens dislocation of 6.0 mm or greater is compared to a fracture with a dislocation less than 6.0 mm among the two age groups, the message is clear: patients of all ages have a statistically significant higher incidence of nonunion if the initial dens dislocation is 6.0 mm or greater (Table 4).

<table>
<thead>
<tr>
<th>Patient's Age</th>
<th>Dens Dislocation</th>
<th>Statistical Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 60 yrs</td>
<td>&lt; 6.0 mm 13%</td>
<td>≥ 6.0 mm 85% p &lt; 0.001, x² = 17.0</td>
</tr>
<tr>
<td>&lt; 60 yrs</td>
<td>7%</td>
<td>75% p &lt; 0.001, x² = 16.3</td>
</tr>
</tbody>
</table>

Based on these data, we advocate 10 to 12 weeks of halo vest immobilization for patients with odontoid Type II fractures associated with less than 6.0 mm dislocation. Irrespective of age, individuals with odontoid Type II fractures and 6.0-mm or greater dens dislocations or those with traumatic injuries that preclude the application of the halo device should be offered early surgical therapy.

Of patients with acute odontoid Type II fractures, 3% have additional bone fragments at the base of the odontoid fracture identified by plain radiographs and CT studies. This unique subtype of odontoid Type II fracture has been labeled Type IIA fracture.4,15,25 They are extremely unstable and are probably associated with significant ligamentous disruption. The additional bone fragments hinder anatomical realignment and inhibit proper bone union with external immobilization. Patients with this fracture subtype should be offered early surgical therapy.

In summary, axis fractures are common spine injuries resulting from vertebral column trauma. Specific fracture subtypes have been classified and much has been learned about the optimal management of each specific injury. Most C-2 fractures can be managed nonoperatively. Most require a 10- to 12-week period of rigid external immobilization with compulsive follow-up monitoring to confirm bone union and stability. Patients with odontoid Type II fractures with greater than 6 mm dens dislocation (irrespective of patient age), those with Type IIA fractures, and those with hangman's odontoid Type III or miscellaneous axis fractures with marked C2–3 subluxation have a higher incidence of nonunion with nonoperative therapy and should be offered early operative reduction with fusion.

### References

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The views of the authors are their own, and are not to be construed as official or reflecting the position of the Department of the Air Force or the Department of Defense.

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