CHAPTER 18

Management of Combination Fractures of the Atlas and Axis in Adults

RECOMMENDATIONS

STANDARDS: There is insufficient evidence to support treatment standards.
GUIDELINES: There is insufficient evidence to support treatment guidelines.
OPTIONS: Treatment of atlas-axis combination fractures based primarily on the specific characteristics of the axis fracture is recommended. External immobilization of most C1–C2 combination fractures is recommended. C1–Type II odontoid combination fractures with an atlantodens interval of 5 mm or more and C1–hangman's combination fractures with C2–C3 angulation of 11 degrees or more should be considered for surgical stabilization and fusion. In some cases, the surgical technique must be modified as a result of loss of the integrity of the ring of the atlas.

RATIONALE

Combined fractures of the atlas and axis often present management challenges owing to the unique anatomy and biomechanics of the atlantoaxial complex and the untoward stresses applied to the atlantoaxial region during trauma. Although most isolated atlas and axis fractures have been managed with cervical immobilization, the occurrence of the two fractures in combination often implies a more significant structural and mechanical injury. Although reports of combination C1–C2 fractures are relatively infrequent, sufficient evidence exists to allow a review of the management of a variety of combinations of atlas and axis fractures. The purpose of this chapter is to examine the available literature to determine successful treatment strategies for individual C1–C2 combination fracture types.

SEARCH CRITERIA

A computerized search of the National Library of Medicine database of the literature published from 1966 to 2001 was undertaken. The medical subject heading "vertebral fracture" in combination with "atlas," "axis," and "human" yielded 1071 references. The abstracts were reviewed, and articles focusing on clinical management and follow-up of combination fractures of the atlas and axis were selected for inclusion. The relative infrequency of these fractures, the small number of case series, and the numerous case reports with pertinent information necessitated rather broad inclusion criteria. Several papers addressing relevant biomechanics and radiology were included. The bibliographies of the selected papers were reviewed to provide additional references. These efforts resulted in 49 articles describing the clinical features and management of acute traumatic atlas and axis combination fractures. Forty-eight of the articles are summarized in *Tables 18.1* and *18.2*. No Class I or II evidence has been generated on the management of these fractures. Treatment options have been formulated on the basis of Class III medical evidence.

SCIENTIFIC FOUNDATION

Overview

In 1920, Sir Geoffrey Jefferson (30) reviewed 46 cases of atlas fractures. Although his article is best known for the characterization of the C1 burst fracture or "Jefferson fracture," Jefferson's series included 19 fractures that were described as "combination fractures" of the atlas and the axis. He noted increased morbidity and mortality for patients with combination injuries. Eleven of the 19 patients he described with C1–C2 combination injuries had significant neurological injuries. In 1986, Levine and Edwards (34) reported their approach to the management of C1–C2 traumatic fracture injuries. They suggested that if an atlas or axis injury was identified, a careful search for other related injuries was indicated. They stressed that each patient and each injury needed to be evaluated independently. They described staged treatment for certain injuries to allow healing of one fracture (usually the atlas) before definitively managing the combination injury (typically the axis fracture). Several of their observations are worthy of consideration in the management of combination fracture injuries of the atlas and axis today.

Incidence

Combination fractures of the C1–C2 complex are relatively common. In reports focusing primarily on odontoid fractures, the occurrence of a concurrent C1 fracture in the presence of a Type II or Type III odontoid fracture has been reported in 5 to 53% of cases (4, 12, 23, 25, 26, 28, 36, 39, 40, 43–45, 47, 49). Odontoid fractures have been identified in 24 to 53% of patients with atlas fractures (18, 32, 35, 45). In the presence of a hang-

man's fracture, the reported incidence of a C1 fracture ranges from 6 to 26% (13, 17, 33, 38, 41, 45). Greene et al. (23) reported on 340 axis fractures and found 48 concurrent atlas fractures (combination injuries), for an incidence of 14%. Ryan and Henderson (45) reviewed 717 spine fractures and found combination atlas-axis fractures in 15% of odontoid fractures and in 9% of hangman's fractures. Gleizes et al. (21) reviewed 784 patients with proximal cervical spine injuries in 2000. One hundred sixteen patients had injuries to C1 and/or C2. Thirty-one patients had C1 fractures in association with a C2 fracture (combination injury), representing 4% of the total cervical spine fracture population and 27% of all C1–C2 fracture injuries.

Morbidity and mortality

Various authors have suggested that the morbidity and mortality of C1–C2 combination fractures is higher than that associated with isolated fractures of either the atlas or the axis (12, 18, 19, 25, 26, 31, 49). Fujimura et al. (19) observed neurological deficits in 82 (34%) of 247 patients with injuries to the C1–C2 complex. Those patients with deficit had either burst fractures or fractures of the posterior arch of C1 or a fracture of the C2 body coupled with an odontoid or hangman's fracture. Several authors have described a high mortality rate with combination fractures, in particular C1 fractures combined with Type II odontoid fractures (18, 25, 26, 49). Fowler et al. (18) found that 6 (86%) of 7 patients with C1–Type II odontoid combination fractures died in the early treatment period. Similarly, Hanssen and Cabanela (26) observed that 5 (83%) of 6 patients with this same combination fracture pattern died within the first 40 days of injury. Both Hanigan et al. (25) and Zavanone et al.(49) reported early deaths associated with C1–Type II odontoid fractures. In other reports on C1–C2 combination fractures, the description of morbidity and mortality has been less remarkable (12, 18). Dickman et al. (12) suggested a 12% incidence of neurological deficit for C1–C2 combination fractures compared with a 0% (0 of 32) and a 2% (2 of 125) incidence for isolated atlas and axis fractures, respectively. Kesterson et al. (31) described four patients with C1–C2 combination fractures. Only 1 patient (25%) had a neurological deficit. Irrespective of the author, the described incidence of morbidity and mortality associated with combination C1–C2 fractures seems to be more than that associated with isolated atlas and axis fractures.

Treatment

Since Jefferson published the original description of C1–C2 combination fracture injuries, nearly every series reviewing either isolated fractures of the atlas or the axis includes some mention of C1–C2 combination fractures. It is difficult to determine the specific treatment provided to and outcome for most of those patients. Several authors have focused their reports specifically on combination C1–C2 fractures and their management (12, 21, 24).

In 1989, Dickman et al. (12) identified 25 cases of acute atlas-axis combination fractures in an overall series of 860 patients with acute cervical fracture injuries. In their experience, C1–C2 combination fractures represented 3% of their total cervical fracture population. Combination injuries represented 43% of acute atlas fractures (25 of 58 patients) and 16% of acute axis fractures (25 of 150 patients). The fractures of C1 and C2 were identified using plain film x-rays in 76 and 92% of the cases, respectively. Computed tomography characterized the combination fracture patterns in all cases. Twelve percent of patients (3 of 25 patients) had neurological deficits at admission. Two patients had acute central cord syndrome, and one patient had a complete neurological injury. The etiology of the injury was a motor vehicle accident in 60% of cases and a fall in 28%. Four main types of atlas-axis fracture combination were identified: C1–Type II odontoid (10 cases, 40%), C1–miscellaneous axis fracture (7 cases, 28%), C1–Type III odontoid (5 cases, 20%), and C1–hangman's-type fracture (3 cases, 12%). The distribution of the atlas fractures was reported as multiple ring fractures in 40%, posterior ring fracture in 28%, unilateral ring fracture in 24%, and lateral mass fracture in 8%. Nonoperative therapy was the initial management strategy in 20 (84%) of 25 of patients. Eighteen patients were placed in a halo orthosis and two in a suboccipital-mandibular immobilizer (SOMI) brace, for a median duration of 12 weeks (range, 10–22 wk). Four patients were treated with early surgical stabilization and fusion based on an atlantoaxial interval of 6 mm or more. Three were treated with posterior C1–C2 wiring and fusion. Follow-up was accomplished in 23 (92%) of 25 patients. Nineteen (95%) of the 20 patients treated with either a halo or SOMI orthosis achieved stability and fusion. Halo immobilization failed in one patient with an initial atlantoaxial interval of 5 mm, and the patient was treated with posterior C1–C2 fusion. All patients treated surgically achieved stability using a posterior fusion technique, four early and one delayed (100%). No

TABLE 18.1. Initial Management of Combination Axis–Atlas Fractures[a]

Combination Fracture Type	Treatment Options
C1–Type II odontoid fracture	
Stable	Collar, halo, surgical fixation/fusion
Unstable (ADI ≥5 mm)	Halo, surgical fixation/fusion
C1–Type III odontoid fracture	Halo
C1–miscellaneous axis	Collar, halo
C1–hangman's fracture	
Stable	Collar, halo
Unstable (C2–C3 angulation ≥11 degrees)	Halo, surgical fixation/fusion

[a] **ADI, atlantodens interval.**

TABLE 18.2. Summary of Reports on Fractures of the Atlas and Axis[a]

Series (Ref. No.)	Description of Study	Evidence Class	Conclusions
Andersson et al., 2000 (2)	Case series of patients >65 yr with odontoid fractures.	III	Includes 3 patients with C1–Type II odontoid fractures. Treatment: Halo, 2 patients. Posterior cervical fusion, 1 patient.
Gleizes et al., 2000 (21)	Retrospective epidemiological review of coincidence of fractures in the upper cervical spine.	III	784 cervical spine injuries. 116 upper cervical spine injuries (C1–C2) (15%). 31/116 (26%) combination of C1 and C2. 70% of all atlas fractures occurred in combination with another fracture. 30% of all hangman's and odontoid fractures occurred in combination with another fracture. 41.9% of patients with combination fractures of the upper cervical spine underwent surgical fixation versus 21.7% of those with isolated injuries.
Muller et al., 2000 (41)	Case series of 39 cases of hangman's fractures.	III	Includes 2 patients with C1 ring fractures (5.1%).
Guiot and Fessler, 1999 (24)	Retrospective review of 10 patients undergoing surgical fixation for combination C1–C2 fractures. 5/10 referred specifically for surgical fixation after failed external immobilization. Average follow-up, 28.5 mo.	III	*Type:* C1–Type II odontoid, 9 patients (90%). C1–Type III odontoid and hangman's, 1 patient (10%). *Technique:* Odontoid screw, 6 (60%). Odontoid screw plus C2 pedicle screws, 1 patient (10%). C1–C2 transarticular screws (posterior), 2 patients (20%). C1–C2 transarticular screws (anterior), 1 patient (10%). *Outcome:* 1 unrelated death. All others fused successfully without other complication.
Henry et al., 1999 (28)	Case series of 61 cases of Type II odontoid fractures treated with anterior screw fixation in which follow-up was available.	III	Includes 10 combination fractures of C1–C2 (16%). C1 burst (Jefferson)-Type II odontoid, 3 patients (5%). C1 anterior arch-Type II odontoid, 3 patients (5%). C1 posterior arch-Type II odontoid, 4 patients (6%). All patients in the series were treated with anterior odontoid screw fixation with a 92% success rate. No problems attributed directly to the presence of the atlas fracture.
Morandi et al., 1999 (40)	Case series including 17 odontoid fractures treated with anterior screw fixation.	III	Includes 2 cases of C1–posterior arch fracture plus a posteriorly displaced Type II odontoid.
Lee et al., 1998 (32)	Retrospective review of 16 cases of atlas fracture.	III	Includes 8 patients with combination C1 and C2 fractures. C1–Type II odontoid, 3 cases. 1 treated with halo immobilization. 2 treated with posterior C1–C2 fusion. C1–Hangman's, 2 cases. Both treated with cervical collar. C1–C2 body fracture, 3 cases. All 3 treated with cervical collar. Authors conclude that the management of the combination fracture should be based on the C2 fracture and that halo immobilization is not always required.
Seybold and Bayley, 1998 (47)	Case series of 57 odontoid fractures.	III	Includes 3 cases of C1 ring fracture plus Type II odontoid. The authors successfully managed two patients with a halo. One patient was treated in a collar with a "poor" result. The overall fusion rate for the Type II odontoid fractures in this series was 65%. No specific effect from the C1 fracture was noted.
Apostolides et al., 1997 (3)	Case report.	III	Patient with anterior ring of C1 fracture and a Type II odontoid in whom halo immobilization failed. Treated successfully with anterior C1–C2 transarticular fixation and an odontoid screw.
Berlemann and Schwarzenbach, 1997 (5)	Retrospective review of 19 patients age >65 with odontoid fractures.	III	Includes 4 patients with C1 fractures and Type II odontoid fractures all treated with anterior odontoid screw fixation.
Greene et al., 1997 (23)	Large review of 340 axis fractures.	III	48 patients with an axis fracture also had an atlas fracture (14%). Specifics on management are not presented, but the authors indicate that the management in these cases was based on the C2 fracture.
Castillo and Mukherji, 1996 (8)	Case report.	III	Includes 1 case of Jefferson fracture plus Type II odontoid treated with halo.
Coric et al., 1996 (9)	Case series of 57 patients with hangman's fractures.	III	Includes 7 cases of combination fracture (C1–hangman's). All were treated based on degree of displacement. If displacement was <6 mm, they were treated with nonrigid immobilization.
Fujimura et al., 1995 (19)	Case series of axis body fractures.	III	Describes 3 patients with C1–miscellaneous body fracture all treated with cervical immobilization. Authors recommend nonoperative treatment except in cases of severe angulation. Philadelphia collar used if minimal angulation.
Polin et al., 1996 (44)	Case series of 62 patients with odontoid fractures.	III	Includes 5 cases of combination C1–C2 fracture (8%). C1–Jefferson-Type II odontoid, 4 cases. C1–miscellaneous C2 body fracture, 1 case. All patients in series managed with either halo or collar.
Coyne et al., 1995 (10)	Retrospective review of 32 patients with odontoid fractures includes 1 combination fracture.	III	1 case of Jefferson-Type II odontoid treated with Gallie fusion.
Fujimura et al., 1995 (19)	Retrospective review of 247 admissions with upper cervical spine fractures. Focuses on 82 patients with neurological deficit.	III	In patients with combined injury of C1–C2, two neurological deficits occurred in patients with posterior arch fracture, burst fracture of the atlas, or body fracture of the axis associated with either an odontoid fracture or hangman's fracture.

TABLE 18.2. ***Continued***

Series (Ref. No.)	Description of Study	Evidence Class	Conclusions
Benzel et al., 1994 (4)	Case series.	III	Includes 1 case of C1, vertically oriented C2 miscellaneous body fracture (treatment not described). The author discusses the possible mechanisms, including hyperextension and axial loading.
Pedersen and Kostuik, 1994 (42)	Case report of 70-yr-old man with fracture dislocation of C1–C2 with 20-mm atlantoaxial displacement.	III	Successfully treated with O–C4 decompression and posterior fusion with complete recovery.
Hanigan et al., 1993 (25)	Case series of 19 patients >80 yr of age with odontoid fractures.	III	Includes 2 patients with a C1–Jefferson-Type II odontoid. 1 patient died in the hospital after being placed in traction. 1 patient had a stable fibrous nonunion after treatment in a halo.
Bohay et al., 1992 (6)	Case series.	III	Includes a case of a C1 burst fracture plus a vertical C2 body fracture successfully treated in a cervical collar alone.
Hays and Bernhang, 1992 (27)	Case series of unusual fractures of the atlas.	III	Includes 2 cases of combination fractures. C1 (anterior arch)–Type II odontoid fracture failed halo treatment, resulting in an O–C2 fusion.
Jeanneret and Magerl, 1992 (29)	Case series of 59 patients with odontoid fractures, 30 of which were treated surgically.	III	Includes 2 cases in which the posterior arch of C1 was not intact. C1–Jefferson-Type II odontoid, 1 patient. C1–posterior arch-Type III odontoid, 1 patient. Authors feel strongly that, if the posterior arch of C1 is not intact, C1–C2 transarticular fixation is indicated. In the comment that follows the article, the point is made that an onlay graft between C1 and C2 posteriorly without wiring of C1 followed by halo immobilization has been used in this situation.
Ryan and Henderson, 1992 (45)	Epidemiological report of 717 spine fractures.	III	Atlas fractures occurred with odontoid fractures (53%) and with hangman's fractures (24%). Odontoid fractures occurred with atlas fractures (15%). Hangman's fracture occurred with atlas fracture (9%).
Craig and Hodgson, 1991 (11)	Case report.	III	Jefferson plus superior facet of axis treated with collar.
Esses and Bednar, 1991 (16)	Case report. Atlas and odontoid fracture.	III	Jefferson plus Type II odontoid in a 34-yr-old man treated successfully with collar only (seen after a 1-mo delay in diagnosis).
Kesterson et al., 1991 (31)	Case series, retrospective review.	III	Includes 4 patients with combination fracture of the atlas and Type II odontoid treated with O–C2 fusion. 1 of these 4 patients had a significant neurological deficit (25%). The authors suggest surgery if unstable and define instability as atlantoaxial interval of >5 mm or lateral mass displacement >7 mm.
Levine and Edwards, 1991 (35)	Case series of 34 patients with atlas fractures.	III	Includes 15 patients with a combination C1–C2 fracture (44%). C1–Type II or Type III odontoid, 8 patients (24%). C1–hangman's, 7 patients (21%). Describes 2 cases in the C1–odontoid fracture group in which the posterior C1 arch altered the treatment plan. In 1 case, a Gallie fusion failed, and in the second, no wiring was used, just onlay bone graft.
Montesano et al., 1991 (39)	Case series of 14 Type II odontoid fractures treated with anterior odontoid screw fixation. Follow-up, 24 mo.	III	7 patients had a C1 fracture (50%). The overall fusion rate was 93%. No problems attributed directly to the C1 fracture.
Zavonone et al., 1991 (49)	Case series of 23 C1–C2 fractures.	III	Includes 2 combination fractures (9%). C1–Type II odontoid: the patient died. C1–hangman's: treated successfully with traction reduction and Minerva.
Fowler et al., 1990 (18)	Case series of 48 atlas fractures from series of 867 C-spine fractures (5.5%).	III	Includes 18 cases with a combination C1–C2 fracture (38% of total series). C1 burst (Jefferson)-Type II odontoid, 6 patients (33%). C1 burst (Jefferson)-Type III odontoid, 1 patient (6%). C1 burst (Jefferson)-miscellaneous axis, 2 patients (11%). C1 burst (Jefferson)-hangman's, 0 patients (0%). C1 arch-Type II odontoid, 8 patients (44%). C1 arch-Type III odontoid, 1 patient (6%). C1 arch-miscellaneous axis, 1 patient (6%). C1 arch-hangman's, 3 patients (16%). These authors present data supporting the increased mortality associated with combination C1–C2 fractures. 6 (86%) of the 7 early deaths had a C1 fracture associated with either a Type II or Type III odontoid fracture.
Dickman et al., 1989 (12)	Retrospective review of 25 patients with fractures of both C1 and C2. Comprises 3% of the overall cervical spine injury cohort (25/860).	III	Four types noted: C1–Type II odontoid, 10 patients (40%). C1–miscellaneous axis, 7 patients (28%). C1–Type III odontoid, 5 patients (20%). C1–hangman's, 3 patients (12%). Neurological deficit in 3/25 patients (12%). Treatment determined by type of C2 fracture. Nonoperative, 84%. Halo, 18 patients. SOMI, 2 patients. In 1 of the C1–Type II patients, halo failed, and patient required C1–C2 fusion. Operative (initial management). C1–Type II odontoid with 6 mm displacement, 3 patients treated with posterior C1–C2 fusion; 1 patient treated with O–C2 fusion because of multiple fractures in C1.

TABLE 18.2. ***Continued***

Series (Ref. No.)	Description of Study	Evidence Class	Conclusions
Fielding et al., 1989 (17)	Case series of 123 hangman's fractures.	III	Includes: C1 arch-hangman's, 10 cases (8%). C1 burst (Jefferson)-hangman's, 2 cases (2%). C1 lateral mass-hangman's, 3 cases (3%). Specifics not given for each subtype, but overall the authors recommend treatment based on the C2 fracture despite the presence of the C1 fracture. Regardless of the C1 fracture, the authors favor an anterior C2–C3 fusion for those patients with angulation >11 degrees, as this group had an 85% nonunion rate with cervical immobilization.
Govender and Charles, 1987 (22)	Case series of upper cervical fractures.	III	Includes 2 cases of combination C1 posterior arch fracture-hangman's fracture, treated successfully with a cervical collar (nonrigid cervical immobilization).
Hanssen and Cabenela, 1987 (26)	Case series of 42 odontoid fractures.	III	Includes 7 combination fractures (17%). C1–Jefferson-Type II odontoid, 6 patients. 5/6 (83%) died within first 40 d. 1/6 developed a stable nonunion. C1–posterior arch-Type II odontoid, 1 patient. Healed with halo immobilization.
Lind et al., 1987 (36)	Case series of 14 odontoid fractures managed in halo orthoses.	III	Includes 1 case of C1–Jefferson-Type II odontoid managed in a halo vest for 12 wk.
Mirvis et al., 1987 (38)	Radiographic review of 27 C2 fractures.	III	Noted 9 associated C1 fractures (26%).
Segal et al., 1987 (46)	Case series of 18 patients with atlas fractures.	III	6 cases were combination C1–C2 fractures. C1–Jefferson-odontoid fracture, 5 cases. 3 treated with halo, 2 with traction followed by halo. C1–Jefferson-hangman's, 1 case treated with a collar.
Levine and Edwards, 1986 (34)	Review article on management of C1–C2 trauma.	III	Comments on combined injuries: 1. The presence of three injuries to the C1–C2 complex is associated with a high likelihood of neurological injury. 2. If 1 injury or fracture is found, one should look carefully for another. 3. Mechanism of injury usually is consistent with the injury observed. 4. Each injury needs to be evaluated individually; for example, the presence of 2 fractures does not always indicate instability (posterior arch of C1 plus a nondisplaced hangman's fracture). 5. Staging of treatment may be required (as described by Lipson et al. below) with allowance of one fracture to heal before treating definitively.
Levine and Edwards, 1985 (33)	Case series of 53 patients with hangman's fracture. Describes stable (Type I hangman's) and unstable (Type II hangman's) groups.	III	Includes 9 cases of Type I hangman's (stable) plus C2 fracture: Type II odontoid, 2 cases. Type III odontoid, 3 cases. Posterior arch, 1 case. Burst (Jefferson), 2 cases. Lateral mass, 1 case. Only 1 case Type II hangman's (unstable) with C2 fracture. Posterior arch, 1 case. Only 1 case treated surgically: Type I hangman's plus Type II odontoid treated with posterior C1–C2 fusion.
Pepin and Hawkins, 1981 (43)	Case series of 41 odontoid fractures.	III	Includes 9 cases of odontoid fracture in combination with another spinal fracture, of which the C1–Jefferson-Type II odontoid was the most common. All treated with either C1–C2 fusion or halo. Author recommends fusion in the elderly.
Effendi et al., 1981 (13)	Case series of 131 hangman's fracture with classification.	III	Includes combination fractures: C1 posterior arch-hangman's, 8 patients (8/131, 6%). Odontoid fracture-hangman's, 2 patients (2/131, 2%). Specific outcomes not presented, but all fused with either anterior or posterior C1–C2 fusion or halo. Overall mortality was 9%.
Ekong et al., 1981 (14)	Case series of 22 patients with odontoid fractures.	III	Includes: C1–Jefferson-Type II odontoid, 1 patient. C1–Jefferson-Type III odontoid, 2 patients. All treated with halo. Halo failed in 1 of the C1 Jefferson-Type III odontoid patients, requiring C1–C2 posterior fusion.
Lipson, 1977 (37)	Case series of 3 cases of atlas fracture plus Type II odontoid.	III	The authors recommend combination therapy of halo immobilization for 10–12 wk until the posterior arch of the atlas fracture has healed, followed by atlantoaxial fusion (Gallie type) to definitively manage the odontoid fracture.
Brashear et al., 1975 (7)	Case series of hangman's fracture.	III	Includes 2 patients with C1 posterior arch fracture plus hangman's treated with reduction and Minerva for 3–6 mo.
Anderson and D'Alonzo, 1974 (1)	Case series of odontoid fractures.	III	Includes 1 patient with combined C1–Type II odontoid fracture treated with O–C2 fusion.
Elliot et al., 1972 (15)	Case series.	III	C1 posterior arch-hangman's, 2 cases treated with immobilization.
Sherk and Nicholson, 1970 (48)	Case report.	III	1 case each of a combination C1–Type II odontoid and a C1–hangman's. Both were treated with immobilization (reduction in traction followed by a Minerva brace) successfully.

[a] **O, occipital; C-spine, cervical spine; SOMI, suboccipital-mandibular immobilizer.**

patient deteriorated during or as a result of treatment. Six patients complained of persistent neck pain or limitation of neck motion. The authors offered a treatment algorithm based on the type and displacement of the axis fracture. They believe that every patient with a C1 or C2 fracture should be studied with computed tomography to rule out a combination injury. When present, atlas fractures in combination with Type II or Type III odontoid fractures with an atlantoaxial interval of 5 mm or more should be considered for early surgical management. The authors stressed that the integrity of the C1 ring must be assessed to determine whether C1–C2 wiring techniques can be used. Their perspectives were offered before the popularization of C1–C2 transarticular screw fixation techniques.

Guiot and Fessler (24), in 1999, described a series of 10 patients with combination atlas-axis fractures treated with surgical stabilization and fusion. In five (50%) of these patients, halo immobilization had failed, and the patients were referred specifically for operative intervention. Ninety percent were patients with C1–Type II odontoid fractures, and the remaining patient had a C1–Type III odontoid combination fracture injury. One patient died of unrelated causes in the follow-up period. There were no other significant complications in a follow-up period of 28.5 months. All nine other patients accomplished successful fusion. An odontoid screw alone was used in five patients, an odontoid screw plus C2 pedicle screws in one, posterior transarticular screws in two, and anterior transarticular screws in one patient. The authors' indications for surgery included patients with fractures that could not be reduced or maintained with external immobilization and unstable fractures with a high likelihood of nonunion (including evidence of disruption of the transverse atlantal ligament).

Treatment of C1–Type II odontoid combination fractures

The treatment of specific fracture combinations has been the subject of numerous reports. The C1–Type II odontoid fracture combination seems to be the most frequent and the subject of the most variability in treatment strategy. As noted with the management of isolated Type II odontoid fractures, optimal treatment remains controversial (see Chapter 17). Management techniques for C1–Type II odontoid combination fractures include semirigid immobilization (collar), traction and then immobilization in a brace, rigid immobilization (halo, Minerva, SOMI), posterior fusion with and without instrumentation, and anterior odontoid screw fixation. Although Esses and Bednar (16) describe a single cases of C1–Type II odontoid combination fracture managed successfully in a cervical collar, the lower fusion rate described for Type II odontoid fractures managed in a collar alone should be considered when electing this treatment option (see Chapter 17). Sherk and Nicholson (48) described a single patient successfully treated with traction reduction and then immobilization in a Minerva brace. Segal et al. (46) treated two patients with traction and then rigid immobilization. Some authors have described the treatment of C1–Type II odontoid combination fractures with rigid immobilization (halo, SOMI, Minerva) (8, 12, 14, 26, 32, 36, 46). Dickman et al. (12) described five of six patients successfully treated in this way (83% success rate). All six patients had an atlantoaxial interval of less than 6 mm. Halo immobilization failed in one patient with an atlantoaxial interval of 5 mm, and the patient required posterior C1–C2 fusion at 12 weeks postinjury. Segal et al. (46) described three cases of C1–Type II odontoid combination fracture successfully treated with halo immobilization. Andersson et al. (2) described two patients older than 65 years with this combination fracture injury who were successfully treated with a halo device. Seybold and Bayley (47) added two more patients treated with a halo resulting in successful union. Additional single cases managed with halo immobilization have been described (8, 14, 26, 32, 36, 43).

The C1–Type II odontoid combination fracture has been successfully managed with surgical stabilization and fusion. Dickman et al. (12) treated four patients with C1–Type II odontoid combination fractures with early surgical fusion based on an atlantoaxial interval of 6 mm or more. Three patients had posterior C1–C2 fusion, and one patient underwent occipitocervical fusion for multiple fractures of the posterior atlantal arch. Andersson et al. (2) treated one patient with C1–Type II odontoid combination fracture with posterior C1–C2 fusion in a series of elderly patients. Coyne et al. (10) also treated one patient with this injury pattern with a C1–C2 posterior fusion. Several authors have suggested that the C1 arch fracture be allowed to heal before undertaking definitive atlantoaxial arthrodesis for this subtype of combination fractures. Other authors have suggested using onlay bone graft for C1–C2 fusion and then halo immobilization in the setting of posterior C1 arch incompetence (29, 34, 37). Lee et al. (32) described the surgical management of two patients with C1–Type II odontoid combination fractures in whom posterior C1–C2 fusion was performed. Guiot and Fessler (24) described two patients with this combination injury pattern treated posteriorly with C1–C2 transarticular screw fixation and fusion. Some investigators have used anterior odontoid screw fixation in the treatment of C1–Type II odontoid combination fractures. Montesano et al. (39), in 1991, described four cases successfully managed in this fashion. Berlemann and Schwarzenbach (5) published an additional four cases. The report by Guiot and Fessler (24) included six patients in whom odontoid screw fixation was accomplished. These authors added anterior transarticular fixation in one patient. In 1999, Henry et al. (28) described a fusion success rate of 90% in 10 patients with C1–Type II odontoid combination fractures treated with anterior odontoid screw fixation. Apostolides et al. (3) described a single case in which three screws were placed, all from an anterior trajectory, to stabilize the C1–C2 articulation bilaterally and the odontoid fracture. Occipitocervical fusion has been reported in the management of C1–Type II odontoid combination fractures (1, 2, 12, 27, 31, 42). It seems that this approach is reserved for patients with disruption of the C1 arch and gross C1–C2 instability.

In summary, a variety of treatment options have been effective in C1–Type II odontoid combination fractures. External orthoses have been successfully used in the management

of most of these injuries. Combination fractures of this subtype with C1–C2 instability as defined by an atlantodens interval of 5 mm or more have a high failure rate with external immobilization alone and have been successfully managed with operative reduction, internal fixation, and fusion.

Treatment of C1–Type III odontoid combination fractures

Dickman et al. (12) described five patients with C1–Type III odontoid combination fractures. All were successfully treated with halo immobilization for an average of 12 weeks. Ekong et al. (14) identified two similar cases. One was managed successfully in a halo. In the second patient, halo immobilization failed, and a delayed posterior C1–C2 fusion was required. Guiot and Fessler (24) reported a patient with a C1–Type III odontoid-hangman's combination fracture, which they successfully treated with ventral odontoid screw fixation and then posterior pedicle screw fixation and fusion. It seems that external immobilization is effective in the management of these injuries in most patients.

Treatment of C1–hangman's combination fractures

Most reported combination injuries of the atlas and the posterior elements of the axis have been successfully managed with semirigid or rigid external immobilization (with or without initial traction) (7, 9, 12, 15, 32, 46, 49). Coric et al. (9) and Lee et al. (32) described the successful treatment of nine patients with this combination fracture type with a cervical collar only. Dickman et al. (12) reported three patients with C1–hangman's combination fractures successfully treated with either a halo or SOMI device. The reports of Elliott et al. (15), Brashear et al. (7), Segal et al. (46), Govender and Charles (22), and Zavanone et al. (49) each describe patients with similar injuries successfully treated with nonoperative techniques. As with an isolated unstable hangman's fracture, surgical fixation may be an option. The report by Fielding et al. (17) included 15 patients with C1–hangman's combination fractures. These authors recommended that fractures with angulation between C2 and C3 of 11 degrees or more be treated surgically. These combination fractures with angulation of more than 11 degrees were associated with an 85% nonunion rate with nonoperative management, in their experience. This combination injury subtype seems to be managed effectively with external immobilization alone. Unstable injuries, as defined by C2–C3 angulation of 11 degrees or more, may require surgical management.

Treatment of C1-miscellaneous C2 body combination fractures

Combination fractures of the atlas associated with miscellaneous axis body fractures have been treated with both rigid and nonrigid immobilization (6, 11, 12, 20, 32, 44). Dickman et al. (12) reported seven cases of this combination fracture subtype treated successfully with either a halo or SOMI brace. The cases described by Fujimura et al. (20), Lee et al. (32), Craig and Hodgson (11), and Bohay et al. (6) were all managed successfully with a cervical collar alone. A single case described by Polin et al. (44) was treated with traction and subsequent halo immobilization. Nonoperative management of this combination injury subtype is effective.

SUMMARY

Combination fractures involving fractures of both the atlas and axis occur relatively frequently. A higher incidence of neurological deficit is associated with C1–C2 combination fractures compared with either C1 or C2 fractures in isolation. The C1–Type II odontoid combination fracture seems to be the most common combination injury subtype, and then C1–miscellaneous axis, C1–Type III odontoid, and C1–hangman's combination fractures. No Class I or Class II evidence addressing the management of patients with combination atlas and axis fractures is available. All of the articles reviewed describe case series or case reports containing Class III evidence supporting a variety of treatment strategies for these unique fracture injuries.

In most circumstances, the specifics of the axis fracture will dictate the most appropriate management of the combination fracture injury. As reported for isolated atlas and axis fractures, most atlas-axis combination fractures can be effectively treated with rigid external immobilization. Combination atlas-axis fractures with an atlantoaxial interval of 5 mm or more or angulation of C2–C3 of 11 degrees or more may be considered for surgical fixation and fusion. The integrity of the ring of the atlas must often be taken into account when planning a specific surgical strategy using instrumentation and fusion techniques. If the posterior arch of C1 is inadequate, both incorporation of the occiput into the fusion construct (occipitocervical fusion) and posterior C1–C2 transarticular screw fixation and fusion have been successful.

KEY ISSUES FOR FUTURE INVESTIGATION

The identification of which of the atlas-axis combination fracture subtypes are at greatest risk for nonunion and subsequent instability would be useful in determining appropriate management for combination fracture injuries. A uniform and clinically useful definition of cranial, C1, and C2 instability in association with these fractures would be of benefit. Prospective data collection and case-control studies at many institutions would provide meaningful data addressing these issues. The relative infrequency of combined atlas-axis fractures would make a randomized study difficult. Patients with a C1–Type II odontoid combination fracture should be studied to compare operative and nonoperative management and should be evaluated in terms of management morbidity, long-term success, economic benefit, patient satisfaction, and return to preinjury activities.

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