Management of Acute Combination Fractures of the Atlas and Axis in Adults

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RECOMMENDATIONS

Level III:

The treatment of combination atlas-axis 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 atlanto-dental ratio of ≥ 5 mm and C1-Hangman combination fractures with C2-C3 angulation of ≥ 11 should be considered for surgical stabilization and fusion.

RATIONALE

The unique anatomy and relationship of the atlas and axis vertebra result in a variety of fracture patterns in the setting of significant cervical trauma. Although each of these vertebral bodies is subjected to isolated fractures, combination fractures occur with sufficient frequency to warrant special consideration. Recommendations for the management of acute combination fractures of the atlas and axis were published by the guidelines author group of the Joint Section on Disorders of the Spine and Peripheral Nerves of the American Association of Neurological Surgeons and the Congress of Neurological Surgeons in 2002.[1] The previous guideline was based on Class III medical evidence and recommended that management decisions for combination C1-C2 fractures be based on the fracture characteristics of the axis fracture. The purpose of the current review is to update the medical evidence on the management of acute combination fractures of the atlas and axis in adults.

SEARCH CRITERIA

A National Library of Medicine (PubMed) computerized literature search from 1966 to 2011 was undertaken using Medical Subject Headings in combination with "vertebral fracture": "atlas," "axis," and "human." This strategy yielded 202 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 required rather broad inclusion criteria. The bibliographies of the selected papers were reviewed to provide additional references.

These efforts resulted in 47 manuscripts describing the clinical features and the management of acute traumatic atlas and axis combination fractures and are summarized in Evidentiary Table format. All provide Class III medical evidence.

SCIENTIFIC FOUNDATION

The historic series of 46 atlas fractures described by Sir Geoffrey Jefferson[2] contained 19 fractures that were actually combination fractures of the atlas and the axis (Table 1). The incidence of concurrent atlas and odontoid fracture ranges from 5% to 53% in the literature, and the incidence of combination atlas and Hangman fractures ranges from 6% to 26%.

Gleizes et al[3] compiled incidence data over a 14-year period on combination fracture injuries in the upper cervical spine. The authors concluded that combination fractures are relatively common and require a high level of surveillance to detect. They identified 784 cervical spine injuries, including 116 upper cervical spine injuries. Of these, 31 were combined C1-C2 fractures, representing 4% of the total. The most frequent C1-C2 fracture combinations included combined bipedicular fracture of the axis and

odontoid fracture, combined fracture of the posterior arch of C1 and odontoid fracture, combined Jefferson fracture with odontoid fracture, and C2 articular pillar fracture with odontoid fracture. The authors observed that 70% of atlas fractures, 30% of odontoid fractures, and 30% of C2 traumatic spondylolistheses (Hangman fractures) were involved in a combination fracture injury. It has been suggested that the likelihood of a neurological deficit is greater with combination fractures than with either atlas or axis fractures alone.[4-6] Historically, combination fractures of C1 and C2 have been managed sequentially, as proposed by Levine and Edwards,[7] allowing 1 fracture to heal (usually the atlas) before attempting definitive management of the axis injury.

In 1989, Dickman et al[8] reported their experience with 25 cases of acute atlas-axis combination fractures from an overall series of 860 patients with acute cervical spinal fracture injuries (3%). They identified an incidence of neurological deficit of 12%. Four combination atlas-axis fracture types 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 fracture (3 cases, 12%). Rigid immobilization was the initial management strategy in 20 of 25 of patients (84%) for a median duration of 12 weeks (range, 10-22 weeks). The reported fusion rate of was 95% (19 of 20). Five patients were treated surgically, and all achieved fusion (100%). Four were treated with early surgery based on an atlantoaxial interval of ≥ 6 mm, and 1 patient with an initial atlantoaxial interval of 5 mm failed halo treatment requiring posterior C1-C2 fusion. The authors recommend computed tomography in all patients with either a C1 or a C2 fracture to evaluate for a combination injury. They recommend that atlas fractures in combination with type II or III odontoid fractures with an atlantoaxial interval of ≥ 5 mm be considered for early surgical management.

Guiot and Fessler[9] in 1999 described a series of 10 patients with combination atlas-axis fractures ultimately treated with surgical stabilization with anterior odontoid fixation. Five had failed a previous attempt at halo immobilization. There were 9 C1-type II odontoid fractures and 1 C1-type III odontoid combination fracture injury. There was 1 death unrelated to surgery. All surviving patients achieved fusion. The authors recommended that surgery be considered in patients with fractures that were irreducible or could not be maintained with external immobilization and for unstable fractures with a high likelihood of nonunion.

Treatment of Combination C1-Type II Odontoid Fractures

The treatment of specific C1-C2 fracture combinations has been the subject of numerous reports. Similar to the literature on isolated type II odontoid fracture management (see Management of Isolated Axis Fractures in Adults), the C1-type II odontoid fracture combination fracture injury has generated the most controversy. Options for management of C1-type II odontoid combination fractures include traction followed by immobilization, semirigid immobilization (collar), rigid immobilization (halo, Minerva, sterno-occipital mandibular immobilizer), posterior C1-C2 fusion with and without instrumentation, and anterior odontoid screw fixation.

Several authors have described traction followed by semirigid immobilization as treatment for acute combination C1-C2 fractures.[10,11] Esses et al[12] described the successful treatment of a C1-type II odontoid combination fracture managed in a cervical collar. The decreased union rate reported for type II odontoid fractures managed with nonrigid immobilization must be considered. The majority of reports of combination C1-C2 fractures have described treatment with rigid external immobilization, including the halo, sterno-occipital mandibular immobilizer, and Minerva devices.[8,13-15,47,49] Dickman et al[8] treated 6 patients with $<$ 6-mm atlanto-dens interval with halo immobilization and reported an 83% success rate (5 of 6). The single treatment failure had an atlantoaxial interval of 5 mm and underwent posterior C1-C2 fusion at 12 weeks after injury. Segal et al,[14] Andersson et al,[13] and Seybold and Bayley[15] described a total of 7 additional cases of C1-type II odontoid combination fractures successfully treated with halo immobilization.

Three contemporary case series presenting conflicting arguments on the role of halo immobilization in the treatment of cervical spinal fracture injuries are summarized in Table 2.[16-18] None of these citations contain exclusively C1- C2 combination fractures, thus limiting their use for specific recommendations. They are included to provide perspective on the role of halo immobilization in upper cervical spine fracture management. Longo et al[17] conducted an extensive systematic review on halo vest management of cervical spine injuries. They identified 47 reports describing a total of 1078 patients with cervical spine fractures, including 50 patients with combination C1-C2 fracture injuries (4.6%). Although the specifics of outcome with this subgroup were not presented, the authors concluded after review that the management of upper cervical spine injuries, including combination fracture injuries, with halo immobilization is a safe and effective treatment option. Daentzer and Flörkemeier[16] retrospectively reviewed 29 patients with upper cervical spine injuries treated in a halo vest. They divided the patients into 2 groups: patients $<$ 65 years of age (n = 18) and patients ≥ 65 years of age (n = 11). The fracture subtypes were as follows: type II odontoid fracture (6 patients), type III odontoid fracture (6 patients), combination C1-C2 fractures (6 patients), and other subaxial cervical fractures (11 patients). The outcomes of interest were the clinical and radiological results, treatment complications, and rate of nonunion requiring surgery. Only 2 patients required surgery: 1 patient with an isolated type II odontoid fracture and 1 patient with a type II odontoid fracture in combination with a C1 arch fracture. Both were $>$ 65 years of age. The clinical and radiological results were not statistically significantly different between the 2 patient groups. The incidence of complications and the time interval for fracture healing were greater in the older patient group but were not statistically significant.

TABLE 1. Initial Management of Combination Fractures of the Atlas and Axis in the Adult

Combination Fracture Type	Treatment Options
C1-type II odontoid fractures	
Stable	Collar, halo, surgical fixation/fusion
Unstable (atlanto-dental ratio ≥ 5 mm)	Halo, surgical fixation/fusion
C1-type III odontoid fractures	Collar, halo, surgical fixation/fusion
C1-Hangman fractures	
Stable	Collar, halo
Unstable (C2-C3 angulation ≥ 11°)	Halo, Surgical fixation/fusion
C1-miscellaneous C2 body fractures	Collar, halo

In a more focused study, Tashjian et al[18] reviewed 78 patients > 65 years of with odontoid fractures: isolated type II (n = 50) or isolated type III odontoid fractures (n = 17) and combination C1-C2 odontoid fractures (n = 11) treated with halo immobilization. Treatment included collar (n = 27), halo (n = 34), and operative (n = 17) (4 operation plus halo). Combination fracture outcomes were not specifically described. There were 24 deaths (31%) during the initial hospitalization. Of those patients treated with a halo vest, 42% died compared with a 20% mortality rate among patients not treated in a halo device (P = .03). The incidence of major complications in the halo-treated group was 66% compared with 36% in the nonhalo group (P = .003). The authors concluded that odontoid fractures in the elderly are associated with significant morbidity and mortality and appear to be magnified with the use of a halo immobilization device.

C1-type II odontoid combination fractures considered to be unstable have been successfully managed with surgical stabilization and fusion. Techniques have included posterior C1-C2 fixation (with or without transarticular screws), anterior odontoid screw fixation, and occipitocervical fusion. Dickman et al,[8] Andersson et al,[13] Coyne et al,[19] and Lee et al[20] treated a total of 8 patients with C1-type II odontoid combination fractures with early surgical fusion based on an atlantoaxial interval of ≥ 6 mm. Six patients had posterior C1-C2 fusion, and 1 patient underwent occipital-cervical fusion for multiple fractures of the posterior atlantal arch. Occipitocervical fixation has been used to treat C1-C2 combination fractures by other authors in cases of C1 posterior arch incompetence or gross C1-C2 instability.[8,13] Guiot and Fessler[9] described 2 patients with this combination injury pattern treated posteriorly with C1-C2 transarticular screw fixation and fusion. Multiple authors have reported anterior odontoid fixation with fusion rates exceeding 90%. Montesano et al,[21] Berlemann and Schwazenbach,[55] Guiot and Fessler,[9] Henry et al,[22] and Apostolides et al[23] have reported a combined total of 25 patients with C1-C2 combination fractures treated successfully with anterior odontoid fixation. Cases reported by Guiot and Fessler[9] and Apostolides et al[23] describe the use of anterior transarticular fixation for combination C1-C2 fracture injuries.

More recently, Ben Aïicha et al[24] described the surgical management of 4 patients with combination fractures of the type II odontoid and C1 arch. Two patients were treated with posterior transarticular C1-2 fusion, 1 patient with occipitocervical fusion, and 1 patient with anterior odontoid screw fixation. The authors recommended that the management of patients with C1-C2 combination fracture injuries be based on the type of odontoid fracture and the presence of neurological injury.

Agrillo and Mastronardi[25] reported the successful use of triple anterior screws (odontoid and bilateral transarticular C1-C2) in the management of a combination C1 arch-type II odontoid fracture in a 92-year-old man. The authors concluded that in presence of a potentially unstable type II odontoid fracture with a fractured posterior atlas arch, triple anterior screw fixation is an option, even in the elderly.

Omeis et al[26] described their surgical series of 29 elderly patients with odontoid fractures (type II alone, n = 24; type II in combination with C1 fractures, n = 5) with a mean follow-up of 18 months postoperatively. Twenty-seven patients (93%) were neurologically intact, and 2 patients (7%) presented with a central cord syndrome. Anterior odontoid screw fixation was the treatment offered to 16 patients (55%). Fusion occurred in 6 patients (37.5%); stability occurred in 9 patients (56.2%); and 1 patient (6.3%) required subsequent posterior stabilization and fusion. Posterior fixation and fusion were the initial treatment in 13 patients (45%). Fusion occurred in 4 patients (30.7%), and stability was achieved in 9 patients (69%). The authors reported 1 death and 3 other perioperative complications (10%). Twenty-five of 29 patients (86%) reportedly returned to their previous level of activity. The authors concluded that odontoid fractures in the elderly can be treated surgically with acceptable morbidity and mortality and that the majority of patients can return to their previous level of independence.

In summary, treatment options for C1-type II odontoid combination fractures include external orthoses (both nonrigid and rigid) and surgical fixation with fusion. C1-C2 instability defined by an atlantal-dens interval of ≥ 5 mm or the failure of external immobilization warrants consideration for surgical treatment by one of several acceptable means.

Treatment of Combination C1-Type III Odontoid Fractures

Dickman et al[8] described 5 patients with C1-type III odontoid combination fractures. All were successfully treated with halo immobilization for an average of 12 weeks. Ekong et al[27] identified 2 similar cases. One was managed successfully in a halo device; the second failed halo immobilization and required a delayed posterior C1-C2 fusion. Omeis et al[26] reported a patient with a C1-type III odontoid-Hangman combination fracture that they successfully treated with ventral odontoid screw fixation followed by posterior pedicle screw fixation and fusion. It appears that external immobilization is effective in the management of these injuries in the majority of patients.

TABLE 2. Evidentiary Table: Combination Atlas Axis Fractures

Reference	Description of Study	Evidence Class	Conclusions
Longo et al,[17] *Injury*, 2010	Systematic review of halo management including 50 patients with a combination C1-C2 fracture	III	Available evidence suggests that management of upper cervical spine fracture with halo fixation is safe and effective.
	Individual outcomes of the combination fracture patients are not reported		
Ben Acha,[24] *Orthopaedics and Traumatology, Surgery and Research*, 2009	Retrospective review of 4 patients with a combination fracture of C1 and odontoid	III	Management is recommended based on the type of odontoid fracture and the presence of neurological involvement.
			Posterior wiring is not indicated with C1 posterior arch fracture.
Daentzer and Flörkemeier,[16] *Journal of Neurosurgery: Spine*, 2009	Retrospective review of 6 combination C1-odontoid fractures examining effect of age on management	III	If the conditions for conservative treatment of upper cervical spine injuries with halo fixation are favorable, the clinical and radiological results are similar in patients regardless of their age. There is a tendency for more complications in older patients.
Omeis et al,[26] *Journal of Spinal Disorders and Techniques*, 2009	Retrospective review of 5 elderly patients with combination C1-odontoid fractures	III	Elderly patients with combination C1-odontoid fractures can be treated surgically with acceptable morbidity and mortality rates. The majority of these patients can be mobilized early and return to their previous levels of independence.
Agrillo and Mastronardi,[25] *Surgical Neurology*, 2006	Case report of a 92-year-old patients with a C1-type II odontoid fracture treated with a combination of odontoid and bilateral transarticular C1-C2 anterior screw fixation	III	Triple anterior screw fixation of C1-type II odontoid fracture is an option, even in the elderly.
Tashjian et al,[18] *Journal of Trauma*, 2006	Retrospective review of 11 elderly patients with combination C1-C2 fractures managed with cervical immobilization	III	Odontoid fractures are associated with significant morbidity and mortality in the elderly and appear worse with the use of a halo device.
Andersson et al,[13] *European Spine Journal*, 2000	Retrospective review of 3 elderly patients with combination C1-type II odontoid fractures	III	Either halo or posterior fusion was successful.
Gleizes et al,[3] *European Spine Journal*, 2000	Retrospective review of 784 cervical spine injuries including 31 C1-C2 combination fractures	III	C1 posterior arch-odontoid fractures were a common pattern.
			70% of C1 fractures and 30% of odontoid fractures were associated with a second upper cervical fracture.
Müller et al,[36] *European Spine Journal*, 2000	Retrospective review of combination C1-Hangman fractures	III	Nonoperative management was successful.
Guiot and Fessler,[9] *Journal of Neurosurgery*, 1999	Retrospective review of 10 patients undergoing surgical fixation for combination C1-C2 fractures	III	Surgical fusion with either anterior odontoid screw or posterior transarticular screw fixation was successful.
Henry et al,[22] *Journal of Bone and Joint Surgery: British Volume*, 1999	Retrospective review of 10 patients with C1-type II odontoid treated with anterior screw fixation	III	The presence of the C1 fracture did not reduce the success rate of anterior odontoid screw fixation.
Morandi et al,[37] *Surgical Neurology*, 1999	Retrospective review of 2 cases of C1-posterior arch with a posterior displaced type II odontoid fractures treated with anterior screw fixation	III	Anterior fixation was successful.
Lee et al,[20] *Spine*, 1998	Retrospective review of patients with combination C1-C2 fractures managed with either a halo or a cervical collar	III	Management of the combination fracture should be based on the C2 fracture, and halo immobilization is not always required.

(Continues)

TABLE 2. *Continued*

Reference	Description of Study	Evidence Class	Conclusions
Apostolides et al,[23] *Journal of Neurosurgery*, 1997	Case report of C1-type II odontoid combination fractures failing halo immobilization	III	Anterior C1-C2 transarticular fixation with an odontoid screw was successful.
Berlemann and Schwazenbach,[55] *Acta Orthopaedica Scandinavica*, 1997	Retrospective review of 4 patients > 65 y of age with C1-type II odontoid fractures	III	Anterior odontoid screw fixation was successful.
Greene et al,[38] *Spine*, 1997	Retrospective review of 48 patients with C1-C2 combination fractures	III	Management should be based on the C2 fracture.
Weller et al,[39] *Surgical Neurology*, 1997	Retrospective review of 5 patients > 70 y of age with combination C1-C2 fractures	III	Halo immobilization and posterior fusion both resulted in high rates of fusion, but halo is poorly tolerated in the elderly. Nonrigid immobilization resulted in lower fusion rates.
Coric et al,[28] *Journal of Neurosurgery*, 1996	Retrospective review of 7 patients with a combination of C1-Hangman fractures	III	Nonoperative management was successful. If C2-C3 displacement was > 6 mm, posterior fusion was successful.
Fujimura et al,[56] *Paraplegia*, 1996	Retrospective review of 3 patients of C1-miscellaneous axis body fractures	III	Nonoperative management was successful.
Polin et al,[33] *Neurosurgery*, 1996	Retrospective review of 5 patients with C1-C2 fractures	III	Nonoperative management was successful.
Coyne et al,[19] *Spine*, 1995	Retrospective review of 1 patient with a combination C1-C2 fracture	III	Posterior stabilization was successful.
Fujimura et al,[6] *Paraplegia*, 1995	Retrospective review of 247 admissions with upper cervical spine fractures including 82 patients with neurological deficit	III	In patients with combined injury of C1-C2, neurological deficit 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 a Hangman fracture.
Pedersen and Kostuik,[40] *Journal of Spinal Disorders*, 1994	Case report of a 70-year-old man with fracture dislocation of C1-C2 with 20-mm atlantoaxial displacement	III	Successfully treated with O-C4 decompression, internal fixation, and posterior fusion with complete recovery.
Hanigan et al,[41] *Journal of Neurosurgery*, 1993	Retrospective review of 2 patients > 80 y of age with C1-odontoid fractures	III	Nonoperative management was successful if patients survived the initial postinjury period.
Bohay et al,[35] *Journal of Orthopaedic Trauma*, 1992	Retrospective review of a patient with C1 burst and vertical C2 body fracture treated with a cervical collar	III	Nonoperative management was successful.
Hays and Alker,[42] *Spine*, 1992	Retrospective review of 2 patients with C1 arch and type II odontoid fractures	III	Nonoperative management was successful in 1 case. O-C2 fusion was performed in the other.
Jeanneret and Magerl,[43] *Journal of Spinal Disorders*, 1992	Retrospective review of 2 patients with combination C1-type II or III odontoid fractures	III	The integrity of the posterior arch of C1 should be considered in planning surgical treatment.
Ryan and Henderson,[44] *Injury*, 1992	Epidemiological report of 717 cervical spine fractures	III	Atlas fractures occurred with odontoid fractures (53%) and with Hangman fractures (24%).
			Odontoid fractures occurred with atlas fractures (15%).
			Hangman's fracture occurred with atlas fracture (9%).
Kesterson et al,[45] *Journal of Neurosurgery*, 1991	Retrospective review of 4 patients with C1-type II odontoid fractures treated surgically	III	Surgery should be considered if combination fracture considered unstable as defined by an atlantoaxial interval of > 5 mm or lateral mass displacement > 7 mm.
Levine and Edwards,[46] *Journal of Bone and Joint Surgery: American Volume*, 1991	Retrospective review of 15 patients with combination C1-2 fractures	III	The integrity of the posterior arch of C1 should be considered in planning surgical treatment.
Montesano et al,[21] *Spine*, 1991	Retrospective review of 7 patients with combination C1-type II odontoid fractures treated with anterior odontoid screw fixation	III	Management should be based on the C2 fracture.

(Continues)

TABLE 2. *Continued*

Reference	Description of Study	Evidence Class	Conclusions
Zavanone et al,[4] *Journal of Neurosurgical Sciences*, 1991	Case series of 23 C1-C2 fractures	III	Included 2 combination fractures (9%): C1-type II odontoid: patient died; C1-Hangman: patient treated successfully with traction reduction and Minerva.
Fowler et al,[5] *Journal of Spinal Disorders*, 1990	Retrospective review of 18 patients with combination C1-C2 fractures	III	Data suggest increased mortality associated with combination C1-C2 fractures. Six of the 7 early deaths (86%) had a C1 fracture associated with either a type II or III odontoid fracture.
Dickman et al,[8] *Journal of Neurosurgery*, 1989	Retrospective review of 25 patients with a combination fracture of both C1 and C2	III	Management should be determined based on the type of C2 fracture.
			Surgery with either anterior or posterior approaches can be considered if failure of nonoperative therapy or displacement of the odontoid fracture of $>$ 6 mm.
Fielding et al,[32] *Clinical Orthopaedics and Related Research*, 1989	Retrospective review of 15 patients with a combination C1-Hangman fractures	III	Management should be based on the C2 fracture. Anterior C2-3 fusion should be considered for those patients with C2-3 angulation $>$ 11° because this group has an 85% nonunion rate with cervical immobilization.
Govender and Charles,[47] *Injury*, 1987	Retrospective review of 2 patients with combination C1-odontoid fractures	III	Nonoperative therapy successful.
Hanssen and Cabanela,[48] *J Trauma*, 1987	Retrospective review of 7 patients with combination C1-odontoid fractures	III	Nonoperative therapy successful.
Lind et al,[49] *Spine*, 1987	Retrospective review of 1 patient with C1-type II odontoid fractures managed in a halo orthoses	III	Nonoperative therapy successful.
Segal et al,[14] *Journal of Bone and Joint Surgery: American Volume*, 1987	Retrospective review of 6 cases with combination C1-2 fractures managed with immobilization	III	Nonoperative therapy was successful.
Levine and Edwards,[7] *Orthopedic Clinics of North America*, 1986	Review article on management of C1-C2 traumatic fractures	III	Comments on combined injuries:
			1. The presence of 3 injuries to the C1-C2 complex associated with a high likelihood of neurological injury.
			2. If find 1 injury or fracture, look carefully for another.
			3. Mechanism of injury usually consistent with the injury observed.
			4. Each injury needs to be evaluated individually; eg, the presence of 2 fractures does not always indicate instability (posterior arch of C1 plus a nondisplaced Hangman fracture).
			5. Staging of treatment may be required (as described by Lipson[53] below) with allowing 1 fracture to heal before treating definitively.
Levine and Edwards,[50] *Journal of Bone and Joint Surgery: American Volume*, 1985	Retrospective review of 9 patients with combination C1-odontoid and C1-Hangman fracture	III	Nonoperative therapy successful in most cases. If fracture grossly unstable, posterior fusion can be successful.
Pepin et al,[51] *Clinical Orthopaedics*, 1985	Retrospective review of 9 patients with combination C1-odontoid fractures	III	Nonoperative therapy successful.
Effendi et al,[52] *Journal of Bone and Joint Surgery: British Volume*, 1981	Retrospective review of 2 patients of C1 arch or odontoid fracture with Hangman fracture	III	Management based on the odontoid fracture was successful.

(Continues)

TABLE 2. *Continued*

Reference	Description of Study	Evidence Class	Conclusions
Ekong et al,[27] *Neurosurgery*, 1981	Retrospective review of 3 patients with C1-odontoid fractures	III	Nonoperative therapy successful.
Lipson,[53] *Journal of Bone and Joint Surgery: American Volume*, 1977	Case series of 3 cases of C1-type II odontoid fractures	III	A staged strategy of halo immobilization until the posterior arch of the atlas fracture has healed followed by atlantoaxial fusion to definitively manage the odontoid fracture was successful.
Brashear et al,[29] *Journal of Bone and Joint Surgery: American Volume*, 1975	Retrospective review of 2 patients of C1-Hangman fracture	III	Nonoperative therapy was successful.
Anderson and D'Alonzo,[54] *Journal of Bone and Joint Surgery: American Volume*, 1974	Retrospective review including 1 patient with C1-type II odontoid fractures	III	O-C2 fusion was successful.

Treatment of Combination C1-Hangman Fractures

The combination of C1-Hangman fractures has been successfully treated with external immobilization in the majority of reported cases. Successful treatment with immobilization has been reported with a cervical collar,[28] the halo device, and the sterno-occipital mandibular immobilizer-type orthosis.[4,8,29-31] The report by Fielding et al[32] included 15 patients with combination C1-Hangman fractures. They reported that when the combination Hangman fracture was associated with C2-3 angulation $> 11°$, they considered these C1-C2 combination injuries unstable. Surgical stabilization and fusion were recommended.

Treatment of Combination C1-Miscellaneous C2 Body Fractures

The recommended initial treatment of C1-C2 body fractures as reported in the literature is nonoperative. Both rigid immobilization and nonrigid immobilization have been described with nearly universal success.[6,20,33-35] The Dickman et al[8] series, which included 7 patients with combination C1-C2 body fractures were all successfully treated with either halo or sterno-occipital mandibular immobilizer immobilization.

SUMMARY

Combination fractures of the atlas and axis occur relatively frequently and are associated with an increased incidence of neurological deficit compared with either isolated C1 or isolated C2 fractures. C1-type II odontoid combination fractures are the most common C1-C2 combination fracture injury pattern, followed by C1-miscellaneous axis body fractures, C1-type III odontoid fractures, and C1-Hangman combination fractures. Class III medical evidence addressing the management of patients with acute traumatic combination atlas and axis fractures describes a variety of treatment strategies for these unique fracture injuries based primarily on the specific characteristics of the axis fracture injury subtype.

The type of axis fracture present generally dictates the management strategy for the C1-C2 combination fracture injury. Rigid external immobilization is typically recommended as the initial management for the majority of patients with these injuries. Combination atlas-axis fractures with an atlantoaxial interval of ≥ 5 mm or angulation of C2 on C3 of $\geq 11°$ have been considered for and successfully treated with surgical stabilization and fusion. Surgical options in the treatment of combination C1-C2 fractures include posterior C1-2 internal fixation and fusion or combination anterior odontoid and C1-2 transarticular screw fixation with fusion. Fractures of the posterior ring of the atlas can complicate the surgical treatment of unstable C1-C2 combination fracture injuries. If the posterior arch of C1 is incompetent and a dorsal operative procedure is indicated, occipitocervical internal fixation and fusion, posterior C1-C2 transarticular screw fixation and fusion, and C1 lateral mass-C2 pars/pedicle screw fixation and fusion techniques have been reported to be successful.

KEY ISSUES FOR FUTURE INVESTIGATION

Review of the available literature highlights the lack of prospective data and comparison studies to help guide appropriate treatment of combination atlas-axis fractures. Although immobilization has been recommended as the initial management of choice, the increased morbidity and mortality of halo use in the elderly, the increased rate of nonunion of type II odontoid fractures, and patient preferences all raise the question of the benefit of early surgical fixation and fusion for these injuries. Prospective data derived from appropriately designed comparative studies would assist in determining the most favorable outcome strategies and would provide Class II medical evidence on this topic.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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