

Management of Isolated Fractures of the Atlas in Adults

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KEY WORDS: Atlas fractures, Jefferson fracture, Rule of spence, Transverse atlantal ligament

Neurosurgery 72:127–131, 2013

DOI: 10.1227/NEU.0b013e318276ee2a

www.neurosurgery-online.com

RECOMMENDATIONS

Level III:

- Treatment of isolated fractures of the atlas based on the specific atlas fracture type and the integrity of the transverse atlantal ligament is recommended.
- For an isolated fracture of the atlas with an intact transverse atlantal ligament, cervical immobilization is recommended.
- For isolated fractures of the atlas with disruption of the transverse atlantal ligament, either cervical immobilization alone or surgical fixation and fusion is recommended.

RATIONALE

The isolated fracture of the atlas, or “Jefferson” fracture, has been an injury of historic interest and remains clinically germane. These injuries are rarely associated with neurological sequelae and are typically managed successfully with minimal intervention. Recommendations for their initial management have generally been conservative in the absence of gross spinal instability. Medical evidence-based recommendations for the management of isolated atlas fractures have been previously offered 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 Class III medical evidence supports a recommendation that the treatment of isolated C1 fractures be based on the integrity of the transverse atlantal ligament. The guidelines

author group concluded, “Isolated fractures of the atlas with an intact transverse atlantal ligament may be treated with cervical immobilization alone.” In patients in whom the transverse atlantal ligament was disrupted, the authors concluded that “[these fractures] may be treated with either cervical immobilization or surgical fixation and fusion.” The purpose of this updated review is to identify additional medical evidence on this important topic since the initial 2002 guideline publication.

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 and human. This strategy yielded 582 references. The abstracts were reviewed, and articles addressing clinical management and follow-up of atlas fractures 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 and exclusion criteria. The bibliographies of the selected articles were reviewed to provide additional references and to assess completeness of the literature review.

These efforts resulted in 5 contemporary articles describing acute traumatic atlas fractures not included in the previous version of this guideline. One of these reports provided no new data and was excluded. Although case reports were included in the previous guideline because of the paucity of clinical material on this subject, no new case reports were identified that would affect the previous recommendations. Fourteen contemporary Class III medical evidence case series are summarized in Evidentiary Table

ABBREVIATION: LMD, lateral mass displacement

format and are described in the text. Selected supporting articles are included in the bibliography and contribute to the scientific foundation.

SCIENTIFIC FOUNDATION

Acute fractures of the atlas (C1) represent 1% to 2% of spinal column fractures and account for 2% to 13% of all acute cervical spine fractures.²⁻⁴ First reported by Cooper in 1822, the subsequent historical publication of Jefferson⁵ in 1920, and later reports by Segal et al⁶ and Sherk and Nicholson⁴ have resulted in the use of the term Jefferson fracture to indicate a burst fracture injury of the atlas ring.

A central issue in the management of atlas fractures has been the importance placed on the integrity of the transverse atlantal ligament. The widely quoted rule of Spence (ie, > 6.9-mm lateral mass displacement of C1 over C2 on the open-mouth radiograph suggests transverse atlantal ligament disruption) was based on only 2 combined biomechanical and clinical studies of relatively low quality.^{7,8} It was postulated to describe the severity of the atlas burst injury and to predict transverse ligament disruption. Historically, it has been used to determine/define the stability of burst fractures of the ring of the atlas. Heller et al⁹ in 1993 proposed that this number be adjusted to 8.1 mm as a result of radiographic magnification factors, but the approximate number of 7 mm is generally still cited in the literature.

In 1996, Dickman and colleagues¹⁰⁻¹² reported that magnetic resonance imaging was a more sensitive indicator of transverse atlantal ligament integrity/disruption than the rule of Spence because of the ability to visualize the ligament with magnetic resonance imaging (MRI). They described 39 patients with C1 ring fractures with abnormal signal in the transverse atlantal ligament, including 60% that would not have been defined as unstable with standard radiographs and the rule of Spence. Although of potential significance, the data they provided are Class III medical evidence for a diagnostic test (see Table 1) because of the lack of a true gold standard and their failure to

include the necessary data required for a formal bayesian analysis (eg, a false-positive rate could not be determined from the data provided).¹¹ The authors recommended treatment of atlas fractures based on the MRI findings. Fractures in which the substance of the ligament was injured without associated fracture of the atlas (type I injury) would be considered for early surgical fixation because of inherent instability. External immobilization was recommended for the finding of an avulsion fracture of the atlas at the insertion of the transverse atlantal ligament (type II injury).¹⁰ As with prior reports, the number of patients treated surgically for instability for whom there was outcome data available was limited. Their report provides Class III medical evidence for treatment.

The previous guideline on this topic summarized a number of case series in formulating treatment recommendations, all of which provided Class III medical evidence.³ In 1988, Hadley et al⁴ described a treatment algorithm based on 32 patients with isolated fractures of the atlas. There were no neurological injuries in their group of patients, and all were managed nonsurgically. This pre-MRI study reported that isolated fractures of the atlas could be managed with external immobilization alone (median, 12 weeks), with the type of immobilization determined by the combined lateral mass displacement (LMD) of C1 over C2. Atlas fractures with an LMD < 6.9 mm (12 patients) were successfully treated with a cervical collar. Twenty patients with an atlas fracture with an LMD > 6.9 mm were effectively treated with more rigid immobilization using the halo orthosis or a suboccipital mandibular immobilizer brace. Fowler et al¹³ described 48 patients with acute traumatic atlas fractures. They treated atlas fracture with an LMD < 7 mm with a cervical collar and those with an LMD > 7 mm with traction followed by immobilization in a cervical collar. None of their patients required surgical stabilization. Additional reports of patients with traumatic atlas fractures favored nonoperative management and are summarized in Table 2. Lee et al¹⁴ and Kesterson et al¹⁵ reported a total of 25 patients considered stable with an LMD < 7 mm; all were treated successfully with a cervical collar. All 34 patients with isolated C1 ring fractures in the Levine and Edwards³ retrospective review all healed successfully without surgery. Levine and Edwards treated fractures with an LMD < 7 mm with a cervical collar and those with an LMD > 7 mm with a halo orthosis or traction until healed. Although infrequent, late instability of isolated C1 fractures can occur; therefore, clinical follow-up during and after immobilization is recommended.¹⁶

The 1998 report of Lee et al¹⁴ attempted to characterize atlas fractures into 3 types: anterior or posterior arch fractures (Landell type I), burst fractures (Landell type II), and lateral mass fractures (Landell type III). In general, types I and III were considered stable. Treatment with rigid collar immobilization was recommended. Type II fractures were judged to be either stable or unstable on the basis of an LMD > 7 mm or documented disruption of the transverse atlantal ligament on MRI. A treatment algorithm resulting in cervical immobilization for stable atlas fractures and surgical stabilization for unstable atlas

TABLE 1. Treatment of Atlas Fractures^a

Atlas Fracture Type	Treatment Options
Anterior or posterior arch fractures (type I)	Collar
Anterior and posterior arch (type II, burst)	
Stable (transverse atlantal ligament intact)	Collar, halo
Unstable (transverse atlantal ligament disrupted)	Halo, C1-2 stabilization, and fusion
Lateral mass fractures (type III)	
Comminuted fracture	Collar, halo
Transverse process fractures	Collar

^aLMD, lateral mass displacement.

TABLE 2. Evidentiary Table: Management of Atlas Fractures

Citation	Description of Study	Evidence Class	Conclusions
Kontautas et al, ²² <i>Journal of Spinal Disorders and Techniques</i> , 2005	Retrospective review of 29 patients with atlas fractures including 17 isolated atlas fractures Atlas classification as by Landells and Van Peteghem et al ¹⁷	III	Fusion rate was 96.4%. Isolated nondisplaced atlas fractures can be treated effectively with a rigid cervical collar alone. Unstable fractures if treated with a halo orthosis heal without surgical intervention in > 96% of cases.
Dvorak et al, ²³ <i>Journal of Neurosurgery: Spine</i> , 2005	Retrospective review, radiographic analysis, and cross-sectional outcome assessment performed in patients with isolated atlas fractures	III	Unstable atlas fractures appear to have a poorer outcome than previously believed. No standardized outcome assessments have been published for this population. Limitations of this review include low (60%) response rate and the lack of a comparison group.
Hein et al, ²⁴ <i>Acta Neurochirurgica (Wien)</i> , 2002	Retrospective review of 8 patients with "unstable" Jefferson fractures	III	Halo immobilization is uncomfortable, associated with failure in unstable fractures, and leads to complications in the elderly.
Horn et al, ²¹ <i>Journal of Neurosurgery: Spine</i> , 2006	Retrospective review of 53 patients treated with halo fixation either after trauma or after surgery	III	External halo fixation can be used safely to treat cervical instability in elderly patients. The high complication rate in this population may reflect the significant incidence of underlying associated disease processes in the elderly.
Lee et al, ¹⁴ <i>Spine</i> , 1998	Retrospective review including 12 cases of isolated fracture of the atlas	III	Nonoperative management successful.
McGuire and Harkey, ⁵ <i>Journal of Spinal Disorders</i> , 1995	Two cases of unstable atlas burst fractures treated with posterior transarticular screw fixation and fusion	III	Surgical management can be considered for unstable fractures defined as a prevertebral space > 5 mm and/or LMD > 9 mm.
Levine and Edwards, ³ <i>Journal of Bone and Joint Surgery: American Volume</i> , 1991	Retrospective review of 34 patients with atlas fractures	III	If LMD < 7 mm, collar; if LMD > 7 mm, either halo alone or reduced in traction and maintained until healed (6 wk in traction and 6 wk in halo).
Kesterson et al, ¹⁵ <i>Journal of Neurosurgery</i> , 1991	Retrospective review of 13 patients with isolated atlas burst (Jefferson) fractures	III	Nonoperative management successful.
Fowler et al, ¹³ <i>Journal of Spinal Disorders</i> , 1990	Retrospective review of 48 consecutive atlas fractures divided into burst (30), posterior arch (17), and anterior arch fractures (1)	III	Reduction in traction if LMD > 7.0 mm followed by treatment in collar was successful.
Hadley et al, ¹ <i>Neurosurgery</i> , 1988	Retrospective review of 32 isolated fractures of the atlas	III	Isolated C1 fractures can be managed without early surgical fixation. If the LMD is > 6.9 mm, then Halo immobilization is indicated.
Landells and Van Peteghem, ¹⁶ <i>Spine</i> , 1988	Retrospective review of 35 patients with fractures of the atlas	III	Classification scheme is described based on fracture pattern. Nonoperative management successful in the majority of cases.
Segal et al, ⁶ <i>Journal of Bone and Joint Surgery: American Volume</i> , 1987	Retrospective review including 8 isolated atlas fractures; median follow-up 46 mo	III	Nonoperative management successful.
Kornberg, ¹⁷ <i>Orthopaedic Review</i> , 1986	Case report of unstable atlas burst fracture	III	Fusion appropriate for unstable burst fractures of the atlas (LMD > 6.9 mm).
Schlicke and Callahan, ¹⁹ <i>Clinical Orthopaedics</i> , 1981	Case report of unstable atlas burst fracture	III	Fusion appropriate for unstable burst fractures of the atlas (LMD > 6.9 mm).

fractures was described; however, the series did not include any unstable isolated atlas fractures. Surgical fixation, primarily C1-2 stabilization with fusion, has been reported as treatment for isolated atlas fractures using LMD criteria > 7 mm¹⁶⁻¹⁹ or a predermal interval on lateral x-ray of > 5 mm.¹⁸

This updated medical evidence review identified 4 more recent clinically relevant studies addressing the management of isolated atlas fractures in adults.²⁰⁻²⁴ These 4 publications include patient data and new information. A review by Kakarla et al²⁰ was identified but appeared to essentially summarize the previous guideline published on this topic and provided no new information.

Kontautas et al²² reviewed a series of 29 patients with upper cervical spine injuries. Although the authors described a prospective review, the study appears to be retrospective and is considered Class III medical evidence. There were no comparison groups or control subjects. The authors reported 17 patients with isolated atlas fractures. Thirteen were considered stable and were treated with a cervical collar. All achieved successful union. Four were considered unstable by Spence criteria and were managed with halo immobilization. Seventy-five percent ($n = 3$) healed. The authors concluded that nondisplaced atlas fractures could be treated with a cervical collar alone. They noted that even with halo immobilization, some unstable atlas fractures will require surgical stabilization. This citation supports the previous guideline recommendations, adds support to the collar-only treatment arm for nondisplaced fractures, but does not provide sufficient medical evidence to change the existing recommendations for unstable atlas fractures.

Dvorak et al²³ in 2005 published the first study attempting to address quality-of-life issues in patients with isolated atlas fractures. They surveyed a series of patients treated for atlas fractures using the Short Form-36 and the American Academy of Orthopaedic Surgeons/North American Spine Society pain value scales. They asked patients to compare their postinjury state with their preinjury status. The study included long-term follow-up (mean, 75 months; range, 19-198 months) but had a relatively low response rate (60%). The authors reported that patients who replied to the survey did not perceive themselves to return to their preinjury status after sustaining a traumatic atlas fracture. The presence of an unstable atlas fracture was associated with a worse outcome compared with those who sustained a stable atlas fracture.

Horn et al²¹ specifically reviewed the complications of halo fixation in the elderly population. Although this study did not specifically focus on atlas fractures alone, it is included in this review as an important consideration of treatment-related complications. Patients were included in their review if they were ≥ 70 years of age and were treated with a halo device either as treatment after injury or postoperatively. A total of 53 patients were included, 41 posttrauma and 12 postoperative patients. The analysis of complications of halo immobilization was based on a total of 42 patients on whom follow-up data were available. The perioperative mortality rate in this group from all causes was

$> 20\%$. Two of the deaths were felt to be unrelated to treatment, resulting in the reported 14% perioperative rate. Halo ring and vest complications included respiratory distress ($n = 4$, 9.5%), dysphagia ($n = 6$, 14.3%), and pin-related complications ($n = 10$, 23.8%). The authors concluded that halo immobilization can be accomplished safely in the elderly; however, the high complication rate associated with halo immobilization must be considered. The high perioperative morbidity rate in this report raises concern for surgical fixation of the cervical spine in this age group as well, highlighting the challenges of treating the elderly injured population in general.

Hein et al²⁴ described their clinical experience with 8 patients with unstable atlas burst fractures and provided their working definition of “unstable” atlas fractures: “The unstable atlas burst fracture, Jefferson fracture, is a fracture of the anterior and posterior atlantal arch with rupture of the transverse atlantal ligament and an incongruence of the atlanto-occipital and the atlanto-axial joint facets.” Their experience spanned a 10-year period, emphasizing the relative infrequency of this isolated fracture pattern. Five of their patients were initially treated with immobilization but required late transarticular screw fixation (62.5%). Eventually, all 8 patients they managed required surgical stabilization, all of whom reportedly achieved bony fusion. The authors concluded that although halo immobilization can be considered for the initial management of unstable atlas fractures, the discomfort of prolonged immobilization and the poor healing/union rate associated with immobilization alone should prompt clinicians to offer early surgical stabilization of unstable atlas fractures. This latter opinion is not supported by the data presented. Their retrospective case series without a control group (and no assurance that the entire cohort of treated patients was included) provides, at best, Class III medical evidence that surgical fixation is an option in selected patients with unstable C1 fractures. Their report does not alter the previously published recommendations on this topic.

These more recent clinical articles provide supportive Class III medical evidence on the treatment of patients with isolated atlas fractures. The issue of quality of life is new information and suggests that there may be more long-term morbidity associated with an atlas fracture than previously believed. The complications associated with halo immobilization of atlas/cervical fractures, particularly in the elderly, are highlighted in this review. The definition of the unstable atlas fracture provided by Hein et al may prove useful for future comparative studies.

SUMMARY

No Class I or Class II medical evidence addressing the management of patients with isolated atlas fractures was identified. Class III medical evidence on this topic from case series and case reports supports several treatment strategies for patients with acute isolated fractures of the atlas. One study addressing quality-of-life issues has been published.

Nondisplaced isolated anterior or posterior atlas arch fractures and fractures of the atlas lateral mass (types I and III) have been effectively treated with external cervical immobilization devices. Rigid collars, suboccipital mandibular immobilizer braces, and halo ring-vest orthoses used for 8 to 12 weeks have been described with successful union/healing rates > 96%. There is no medical evidence suggesting the superiority of 1 form of external immobilization over another.

Combined anterior and posterior arch fractures of the atlas (type II or burst fractures) with an intact transverse atlantal ligament (stable) have been effectively managed with use of a rigid collar, a suboccipital mandibular immobilizer brace, or a halo orthosis for a duration of 10 to 12 weeks.

Combined anterior and posterior arch fractures of the atlas (type II or burst fractures) with evidence of transverse atlantal ligament disruption (unstable) have been effectively treated with either rigid immobilization alone (halo orthosis) for a period of 12 weeks or surgical stabilization and fusion. Consideration of the potential complications of halo immobilization, particularly in the elderly, is suggested and must be balanced against the potential morbidity/mortality associated with surgical treatment for these fracture injuries.

Criteria proposed to determine transverse atlantal ligament injury with associated C1-C2 instability include the sum of the displacement of the lateral masses of C1 on C2 of > 6 to 9 mm on a plain open-mouth x-ray (or 8.1 mm, the rule of Spence corrected for magnification), a prevertebral space of > 5 mm in adults, and evidence of transverse atlantal ligament disruption or avulsion on MRI.

KEY ISSUES FOR FUTURE INVESTIGATION

The main issue in the management of patients with isolated fractures of the atlas remains being able to predict which patients with an unstable atlas fracture will fail to respond to immobilization alone and require surgical stabilization and fusion. Because of the relative infrequency of these fractures, registry data with a retrospective analysis using case-control study design appear to be the most feasible means to study this issue and provide Class II medical evidence.

Disclosure

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

REFERENCES

1. Isolated fractures of the atlas in adults. In: Guidelines for the management of acute cervical spine and spinal cord injuries. *Neurosurgery*. 2002;50(3 suppl):S120-S124.
2. Hadley MN, Dickman CA, Browner CM, Sonntag VK. Acute traumatic atlas fractures: management and long term outcome. *Neurosurgery*. 1988;23(1):31-35.
3. Levine AM, Edwards CC. Fractures of the atlas. *J Bone Joint Surg Am*. 1991;73(5):680-691.
4. Sherk HH, Nicholson JT. Fractures of the atlas. *J Bone Joint Surg Am*. 1970;52(5):1017-1024.
5. Jefferson G. Fractures of the atlas vertebra: report of four cases and a review of those previously reported. *Br J Surg*. 1920;7:407-422.
6. Segal LS, Grimm JO, Stauffer ES. Non-union of fractures of the atlas. *J Bone Joint Surg Am*. 1987;69(9):1423-1434.
7. Fielding JW, Cochran GB, Lawsing JF 3rd, Hohl M. Tears of the transverse ligament of the atlas: a clinical and biomechanical study. *J Bone Joint Surg Am*. 1974;56(8):1683-1691.
8. Spence KF Jr, Decker S, Sell KW. Bursting atlantal fracture associated with rupture of the transverse ligament. *J Bone Joint Surg Am*. 1970;52(3):543-549.
9. Heller JG, Viroslav S, Hudson T. Jefferson fractures: the role of magnification artifact in assessing transverse ligament integrity. *J Spinal Disord*. 1993;6(5):392-396.
10. Dickman CA, Greene KA, Sonntag VK. Injuries involving the transverse atlantal ligament: classification and treatment guidelines based upon experience with 39 injuries. *Neurosurgery*. 1996;38(1):44-50.
11. Dickman CA, Sonntag VK. Injuries involving the transverse atlantal ligament: classification and treatment guidelines based upon experience with 39 injuries. *Neurosurgery*. 1997;40(4):886-887.
12. Greene KA, Dickman CA, Marciano FF, Drabier J, Drayer BP, Sonntag VK. Transverse atlantal ligament disruption associated with odontoid fractures. *Spine (Phila Pa 1976)*. 1994;19(20):2307-2314.
13. Fowler JL, Sandhu A, Fraser RD. A review of fractures of the atlas vertebra. *J Spinal Disord*. 1990;3(1):19-24.
14. Lee TT, Green BA, Petrin DR. Treatment of stable burst fracture of the atlas (Jefferson fracture) with rigid cervical collar. *Spine (Phila Pa 1976)*. 1998;23(18):1963-1967.
15. Kesterson L, Benzel E, Orrison W, Coleman J. Evaluation and treatment of atlas burst fractures (Jefferson fractures). *J Neurosurg*. 1991;75(2):213-220.
16. Landells CD, Van Peteghem PK. Fractures of the atlas: classification, treatment and morbidity. *Spine (Phila Pa 1976)*. 1988;13(5):450-452.
17. Kornberg M. Atypical unstable burst fracture of the atlas: treated by primary atlantoaxial fusion. *Orthop Rev*. 1986;15(11):727-729.
18. McGuire RA Jr, Harkey HL. Primary treatment of unstable Jefferson's fractures. *J Spinal Disord*. 1995;8(3):233-236.
19. Schlicke LH, Callahan RA. A rational approach to burst fractures of the atlas. *Clin Orthop Relat Res*. 1981;154:18-21.
20. Kakarla UK, Chang SW, Theodore N, Sonntag VK. Atlas fractures. *Neurosurgery*. 2010;66(3 suppl):60-67.
21. Horn EM, Theodore N, Feiz-Erfan I, Lekovic GP, Dickman CA, Sonntag VK. Complications of halo fixation in the elderly. *J Neurosurg Spine*. 2006;5(1):46-49.
22. Kontautas E, Ambrozaitis KV, Kalesinskas RJ, Spakauskas B. Management of acute traumatic atlas fractures. *J Spinal Disord Tech*. 2005;18(5):402-405.
23. Dvorak MF, Johnson MG, Boyd M, Johnson G, Kwon BK, Fisher CG. Long-term health-related quality of life outcomes following Jefferson-type burst fractures of the atlas. *J Neurosurg Spine*. 2005;2(4):411-417.
24. Hein C, Richter HP, Rath SA. Atlantoaxial screw fixation for the treatment of isolated and combined unstable Jefferson fractures: experiences with 8 patients. *Acta Neurochir (Wien)*. 2002;144(11):1187-1192.