

Isolated Fractures of the Atlas in Adults

RECOMMENDATIONS

STANDARDS: There is insufficient evidence to support treatment standards.

GUIDELINES: There is insufficient evidence to support treatment guidelines.

OPTIONS: Treatment options in the management of isolated fractures of the atlas are based on the specific atlas fracture type. It is recommended that isolated fractures of the atlas with an intact transverse atlantal ligament be treated with cervical immobilization alone. It is recommended that isolated fractures of the atlas with disruption of the transverse atlantal ligament be treated with either cervical immobilization alone or surgical fixation and fusion.

RATIONALE

The atlas vertebra is subject to a variety of acute fracture injuries and may be associated with other cervical fractures and ligamentous traumatic injuries (4, 8, 25, 26, 31). Although the treatment of atlas fractures in combination with other cervical fracture injuries is most commonly linked to the treatment of the associated injury (8), isolated fractures of the atlas occur with sufficient frequency to warrant review.

The medical literature addressing the management of fractures of the atlas was examined using evidence-based medicine techniques to determine the optimal treatment for isolated atlas fractures, including isolated anterior or posterior arch fractures, anterior and posterior arch fractures (burst fractures), lateral mass fractures, comminuted fractures, and transverse process fractures.

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" combined with "atlas" and "human" yielded 360 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 collected case series, and the numerous case reports with pertinent information required rather broad inclusion and exclusion criteria. Several papers addressing relevant background information such as biomechanics and radiology were included. The bibliographies of the selected articles were also reviewed to provide additional references and to assess completeness of the literature review. These efforts resulted in 32 articles describing acute traumatic atlas fractures. Ten Class III articles (eight case series and two case reports) documenting treatment of patients with atlas fractures are summarized in *Table 16.1*. The remaining 22 articles are included in the reference list and contribute to the scien-

tific foundation. Treatment options are summarized in *Table 16.2*.

SCIENTIFIC FOUNDATION

Atlas fractures account for approximately 1 to 2% of all fractures of the human spinal column and roughly 2 to 13% of all acute cervical spine fractures (8, 21, 30). The first known fracture of the atlas was demonstrated at autopsy by Cooper in 1822 and has been the subject of a series of historical publications (28). In 1920, Jefferson (15) reviewed 42 previously described cases of atlas fracture and added 4 new cases. Although his article documents a variety of atlas fracture patterns, it is best known for the characterization of the "Jefferson fracture," a burst fracture injury of the atlas ring (10). In 1945, Hinchey and Bickel (13a) added 112 cases of atlas fracture to the literature. Sherk and Nicholson summarized an additional 73 cases in 1970 (30).

Spence et al. (31), in 1970, reported their findings of a study of the mechanism of atlas fracture and potential rupture of the transverse atlantal ligament. Using 10 cadaveric specimens, the authors studied the application of force required to fracture C1 and to rupture the transverse ligament (range, 38–104 kg; mean, 58 kg). The sum of the excursion of the C1 lateral masses over the C2 lateral masses after traumatic injury ranged from 4.8 to 7.6 mm (mean, 6.3 mm). The authors concluded that if the sum of lateral mass displacement (LMD) of C1 over C2 on the anteroposterior radiographic image is more than 6.9 mm, then the transverse atlantal ligament is "probably torn." In a follow-up clinical and biomechanical study, Fielding et al. (5) confirmed these findings. These two studies, completed before the era of magnetic resonance imaging (MRI), are the basis for the widely quoted "rules of Spence" (i.e., >6.9 mm LMD = transverse atlantal ligament disruption) offered to assist in the management of patients with isolated atlas fractures. Subsequently, Heller et al. (12) reported their observations on 35 open-mouth odontoid films using calibration markings to assess radiographic magnifica-

Isolated Fractures of the Atlas in Adults

tion. They found an 18% magnification factor on open-mouth odontoid-view x-rays. Applying this information to the evaluation of atlas burst fractures by means of the rules of Spence suggests that the sum of the LMD measurements indicating atlantal transverse ligament disruption should be increased from 6.9 to 8.1 mm. This study pointed out the difficulty in using plain radiographic measurements to assess the integrity of the transverse atlantal ligament after acute traumatic atlas fracture.

Hadley et al. (8) reported a series of 57 patients with atlas fractures, representing 6.6% of their series of cervical fractures in 1988. The authors managed 32 patients with isolated atlas fractures, none of whom sustained neurological injury. The authors based their treatment recommendations on the degree of LMD in each patient. Twelve patients had nondisplaced atlas fractures. Of these, 10 were treated with a rigid collar, one with a soft collar, and one with a suboccipital-mandibular immobilizer (SOMI). The duration of treatment for these patients was 8 to 12 weeks. Fifteen patients had an LMD of less than 7 mm. Eight were treated with a rigid collar, three with a SOMI, and four with a halo immobilization brace for 10 to 12 weeks. The remaining five patients had an LMD of more than 7 mm and were managed with a halo orthosis. These five patients were treated for 12 to 16 weeks. Of the 32 patients, 29 were available for long-term follow-up (median, 40 mo). Three complained of neck pain. All were successfully treated. No patient required subsequent surgical fixation. The authors concluded that isolated fractures of the atlas are effectively managed with external immobilization alone for 12 weeks (median duration). Atlas fractures with an LMD of more than 6.9 mm required more rigid immobilization (halo orthosis) than those with an LMD of less than 6.9 mm (cervical collar). Levine and Edwards (21) described their experience with 34 patients with isolated atlas fractures in 1991. They followed a similar treatment algorithm with similar success.

Fowler et al. (6) reported a series of 48 consecutive atlas fracture patients, representing 5.5% of all cervical fractures in their experience. In their series, 33% of their patients had other associated cervical spine fractures. Atlas fractures were divided into burst ($n = 30$), posterior arch ($n = 17$), and anterior arch fractures ($n = 1$). None of the patients with an isolated atlas fracture presented with neurological deficit. These authors suggested treatment with closed traction reduction of isolated atlas fractures if the LMD is more than 7.0 mm, and then immobilization in a rigid collar. No patient in this series underwent surgical fixation. All were effectively treated with this management scheme at last follow-up, although the duration of treatment was not specified. In 1991, Kesterson et al. (16) reported their series of 17 cases of atlas fractures. Thirteen were isolated atlas fractures and were considered stable. All were successfully managed with rigid cervical immobilization (nine collar, one SOMI, one halo, two Minerva). Again, the duration of treatment was not specified. Several other authors have described the successful treatment of isolated atlas frac-

tures with rigid cervical immobilization, using similar management principles (9, 13, 20, 29, 32).

Landells and Van Peteghem (18) described a series of 35 patients with atlas fractures, representing 4.7% of their institutional experience with acute cervical fracture injuries. The authors categorized atlas fractures into three types. Type I fractures involved a single arch and occurred in 16 of their 35 patients. Type II fractures were burst fractures and represented 13 of the 35 isolated fractures they treated. Type III fractures were atlas lateral mass fractures identified in 6 of the 35 patients. The authors used the original rules of Spence to assist with the identification of stability and noted four patients with an LMD of more than 6.9 mm. Regardless of the fracture type or stability, all fractures except one were initially treated with external immobilization for an unreported length of time. The one exception was a patient with a Type I fracture who underwent early surgery with C1–C2 wiring and fusion. The reason for the exception is not made clear in the text. Only 1 of 34 patients treated with external immobilization required surgery for late instability. The authors observed no relationship between successful treatment and the amount of initial LMD. They recommended that atlas fractures be initially treated with rigid external immobilization. They noted that late instability can occur and recommended clinical follow-up of these patients.

Clinically observed atlas fracture patterns can be reproduced in cadaveric experimental models of axial loading (11). In a series of biomechanical studies, Oda et al. (24, 25) and Panjabi et al. (26) reproduced these atlas fracture patterns with axial loading and found that the burst fracture was associated with postinjury hypermobility at C1–C2. These authors described a 42% increase in flexion/extension motion, a 24% increase in lateral bending, and a 5% increase in axial rotation. They found that in all instances of transverse atlantal ligament disruption, the atlantodens interval was more than 3 mm. The authors concluded that the atlantodens interval was the most reliable predictor of transverse ligament disruption in adults after acute C1 fracture.

McGuire and Harkey (22), in 1995, described two cases of unstable atlas burst fractures treated with surgical fixation and fusion. The fractures were thought to be unstable based on a predental space more than 5 mm and an LMD more than 9 mm, respectively. Both were treated with posterior C1–C2 transarticular screw fixation and fusion with good results. The authors reported that transarticular screw fixation obviated the need for halo immobilization postoperatively. Several other authors have reported successful surgical fixation and fusion for atlas fractures when they are associated with disruption of the transverse ligament with resultant instability (17, 18, 27). These few patients were treated with posterior C1–C2 wiring and fusion procedures and were managed in rigid orthoses (halo, Guilford brace) for 12 to 16 weeks postoperatively.

More recently, it has been proposed that MRI is a more sensitive indicator of transverse atlantal ligament disruption than

TABLE 16.1. Summary of Reports on Treatment of Fractures of the Atlas in Adults^a

Series (Ref. No.)	Description of Study	Evidence Class	Conclusions
Lee et al., 1998 (20)	Retrospective review including 12 cases of isolated atlas fracture.	III	All treated successfully with external immobilization. Treatment algorithm proposed: <i>Stable</i> , treat with collar 12 wk. <i>Unstable</i> , proposes surgical fixation. (Instability defined as lateral mass displacement >7 mm or MRI evidence of transverse ligament disruption).
McGuire and Harkey, 1995 (22)	2 cases of unstable atlas burst fracture treated with posterior transarticular screw fixation and fusion.	III	Considered unstable based on prelateral space >5 mm and LMD >9 mm. Both treated successfully. A cervical collar was used postoperatively.
Levine and Edwards, 1991 (21)	Retrospective review of 34 patients with atlas fractures. Median follow-up, 4.5 yr.	III	If lateral mass displacement <7 mm, patients treated with collar, and if >7 mm, patients treated with either halo alone or reduced in traction and maintained until healed (6 wk in traction and 6 wk in halo). No patients treated surgically.
Kesterson et al., 1991 (16)	Retrospective review including 13 patients with isolated atlas burst (Jefferson) fracture.	III	All successfully treated with immobilization.
Fowler et al., 1990 (6)	Retrospective review of 48 consecutive atlas fractures divided into burst (30), posterior arch (17), and anterior arch fractures (1).	III	Authors suggest reduction by traction if LMD >7.0, followed by collar. No patients underwent surgical fixation.
Hadley et al., 1988 (8)	Retrospective review including 32 isolated fractures of the atlas. Median follow-up, 40 mo on 29/32 fractures.	III	The following treatment patterns were recognized: LMD >7 mm (5 patients): treated with halo. LMD 0–7 mm (15 patients): 4 treated in halo, 11 treated in SOMI. LMD none (12 patients): treated in rigid collar. None of these isolated C1 fractures sustained neurological injury or required surgery.
Landells and Van Peteghem, 1988 (18)	Retrospective review of 35 patients with fracture of the atlas.	III	3 complained of neck pain; otherwise, all were successfully treated. Authors' recommendation: isolated C1 fractures can be managed without early surgical fixation. If the LMD >6.9 mm, then halo immobilization is indicated. The authors outline a classification scheme: <i>Type I</i> : single arch (16), most prevalent and most often associated with other fractures. <i>Type II</i> : burst fracture (13), most often in isolation, only 1/13 with deficit. <i>Type III</i> : lateral mass fracture (6). Treatment not standard but 34 patients were treated with rigid external immobilization. Only 1 patient treated with early surgery (Type I fracture treated with C1–C2 fusion). One patient required surgery in follow-up.
Segal et al., 1987 (28)	Retrospective review including 8 isolated atlas fractures. Median follow-up, 46 mo.	III	56% of patients reported significant symptoms at 1 yr (neck pain, scalp dysesthesias). Authors argue for conservative measures with traction and immobilization with careful follow-up.
Kornberg, 1986 (17)	Report of a single case of unstable atlas burst fracture.	III	2/4 patients with a comminuted fracture, described as a unilateral avulsion of the transverse ligament attachment and adjacent arch fracture, developed a nonunion and remained symptomatic at follow-up. The authors recommend that these patients be considered for the "most effective immobilization." None of the patients underwent surgical fixation.
Schlicke and Callahan, 1981 (27)	Report of a single case of unstable atlas burst fracture.	III	Author feels that fusion is appropriate for unstable burst fractures of the atlas (LMD >6.9 mm) and describes a case of posterior arch disruption in which they were still able to perform C1–C2 posterior fusion because one arch remained connected to lateral mass. Case of unstable burst fracture of the atlas with LMD of 12 mm. The authors propose a treatment algorithm of considering surgery for disruption of the transverse ligament (LMD >6.9 mm).

^a MRI, magnetic resonance imaging; LMD, lateral mass displacement; SOMI, suboccipital-mandibular immobilizer.

TABLE 16.2. Treatment Options for Atlas Fractures

Atlas Fracture Type	Treatment Options
Anterior or posterior arch fractures	Collar
Anterior and posterior arch (burst):	
<i>Stable (transverse atlantal ligament intact)</i>	Collar, halo
<i>Unstable (transverse atlantal ligament disrupted)</i>	Halo, C1–C2 stabilization and fusion
Lateral mass fractures:	
<i>Comminuted fracture</i>	Collar, halo
<i>Transverse process fractures</i>	Collar

the rules of Spence (3, 4, 7). Dickman et al. (4) described two types of isolated transverse atlantal ligament injuries they identified on MRI. In Type I, the substance of the ligament is injured without associated fracture of the atlas. Type II involves an avulsion fracture of the atlas at the insertion of the transverse atlantal ligament. The authors concluded that patients with Type I injuries should be treated with early surgical fixation because of the inherent instability at C1–C2 after ligamentous disruption. They favor rigid external immobilization for patients with Type II ligament fracture injuries. Applying MRI to their series of 39 patients with atlas and/or axis fractures, the authors reported that the use of standard cervical x-rays and the rules of Spence would have failed to identify 60% of the fractures they found with associated disruption of the transverse atlantal ligament (as determined by MRI) (3).

Lee et al. (20) described 16 patients with atlas fractures. These included six isolated anterior or posterior arch fractures (Landell's Type I), four burst fractures (Landell's Type II), and six lateral mass fractures (Landell's Type III). Twelve of the 16 fracture injuries were isolated atlas fractures and were judged to be stable as determined by integrity of the transverse ligament either by MRI or by LMD criteria. All 12 were successfully treated with rigid collar immobilization for 10 to 12 weeks. The authors recommended a treatment algorithm of cervical immobilization for stable atlas fractures and surgical fixation and fusion for unstable atlas fractures and unstable C1–C2 combination fracture injuries. Their series, however, did not include any patient with an unstable isolated atlas fracture, nor any patient with an isolated atlas fracture who required surgical management.

Unusual isolated atlas fractures have been described in the literature, often as radiographic curiosities (1, 11, 14, 19, 23). None of the cases for which clinical information was provided needed surgical treatment. Fractures of the transverse process of the atlas have been described, including one of the cases described by Jefferson in 1920 (2, 15). Although injury to the vertebral artery has been associated with fractures through the C1 transverse foramen, the bony C1 injury has not required surgical fixation and has been treated with immobilization alone.

SUMMARY

There are no Class I or Class II studies that address the management of patients with isolated atlas fractures. All of the articles reviewed described case series or case reports that provide Class III evidence supporting several treatment strat-

egies for patients with acute C1 fracture injuries. Isolated anterior or posterior atlas arch fractures and fractures of the atlas lateral mass have been effectively treated with external cervical immobilization devices. Rigid collars, SOMI braces, and halo ring-vest orthoses have all been used for a duration of treatment of 8 to 12 weeks with good results. No study has provided evidence for using one of these devices over the other. Combined anterior and posterior arch fractures of the atlas (burst fractures) with an intact transverse atlantal ligament (implying C1–C2 stability) have been effectively managed with the use of a rigid collar, a SOMI brace, or a halo orthosis for a duration of 10 to 12 weeks. Combined anterior and posterior arch fractures of the atlas (burst fractures) with evidence of transverse atlantal ligament disruption have been effectively treated with either rigid immobilization alone (halo orthosis) for a period of 12 weeks, or surgical stabilization and fusion. The type of C1–C2 internal fixation and fusion procedure performed may influence the need for and duration of postoperative immobilization.

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 more than 8.1 mm on plain x-rays (rules of Spence corrected for magnification), a predental space of more than 3.0 mm in adults, and MRI evidence of ligamentous disruption or avulsion.

KEY ISSUES FOR FUTURE INVESTIGATION

The ability to identify the atlas fracture types at greatest risk of nonunion and subsequent instability is a key issue in determining appropriate management. Prospective data collection generating case-control studies at multiple institutions would be feasible and useful in examining this issue. The relative infrequency of isolated atlas fractures would make a randomized study less likely to be implemented. A uniform and clinically useful definition of instability in association with isolated atlas fractures would be of benefit. The subgroup of patients with isolated atlas fractures with transverse ligament disruption that can be managed either by external immobilization alone or surgical fixation and fusion should be examined in terms of long-term success, economic benefit, patient satisfaction, and return to preinjury activities. The relative paucity of patients with atlas fractures treated with

surgical stabilization and fusion described in the literature limits the ability to address these issues at present.

Reprint requests: Mark N. Hadley, M.D., Division of Neurological Surgery, University of Alabama at Birmingham, 516 Medical Educational Building, 1813 6th Avenue South, Birmingham, AL 35294-3295.

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