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C1 Lateral Mass-C2 Pedicle Screws and Crosslink Compression Fixation for Unstable Atlas Fracture

Jun Tan, MD,* Lijun Li, MD,* Guixin Sun, MD,* Lie Qian, MD,* Mingjie Yang, MD,*
Cheng Zeng, MD,* Honglin Teng, MD,† and Lianshun Jia, MD‡

Study Design. Primary clinical trial of limited fixation for unstable Atlas fracture.

Objectives. To clinically validate feasibility, safety and value of the C1 later-mass screw C2 pedicle screw and crosslink compression fixation technique.

Summary of Background Date. In previous clinical studies, several techniques have been introduced to fix Atlas fracture. But all these treatments have intrinsic disadvantages. Now seeking a means of limited internal fixation has become a worthwhile subject of clinical study.

Materials and Methods. From January 2001 to December 2004, 17 cases of atlas fracture were diagnosed consecutively, 11 cases were operated on with C1 lateral mass and C2 pedicle screws and crosslink fixation, of whom 6 patents had axial instability and rupture of transverse ligament, 1 patient had C2 laminal fracture, and the remaining 4 patients had axial instability. With the assistant of regional anatomy study and fluoroscopy C1 lateral mass screws and C2 pedicle screws were implanted in place, between which connecting rods were applied bilaterally. A crosslink compression was applied between the 2 rods to achieve realignment of C1 lateral mass fracture and C0–C1–C2 into the anatomic position. C1–C2 fusion with posterior bone grafting was performed in patients with axial instability or transverse ligament discontinuity.

Results. Operative time ranged from 90 to 176 minutes with a mean of 124 minutes. Intraoperative blood loss ranged from 270 to 1200 mL with a mean of 432 mL. There were no neurologic deficits, vertebral artery related complications or other complications in all patients. No deterioration of the neurologic deficits was noticed 5 days after operation when the patients were brace fixed and began to ambulate. No cerebral hemodynamic deficit was observed in this patient. Radiograph examination showed bone fusion and stability in all patients 3 months after operation. Healing of C2 fracture was confirmed by computed tomography scan.

Conclusion. Osteosynthesis of the atlas by C1 lateral mass screws C2 pedicle screws and crosslink compression fixation is an ideal option for C1 burst fracture with or without rupture of the transverse ligament. The procedure allows for partially physiologic reconstruction of the C0–C1–C2 joint and shortens external fixation.

Key words: fracture, lateral mass screws, pedicle screws, crosslink. **Spine 2009;34:2505–2509**

The atlas is unique vertebra between the occipital condyle and the axis, composed of the tumescent left and right lateral masses, the anterior and posterior tubercles, and the arcuate structure linking them. It is the transition link of the occipitocervical junction, maintaining axial and rotation stabilities by osseous anastomosis and ligamentous connection and limitation. Some type of atlas fracture may result in instability.

Classic treatment for atlantal occipitocervical instability includes continuous skull traction, cephalocervicothoracic plaster fixation, halo vest traction and fixation, and occipitocervical fusion. The first 3 treatments need sufficient time for bone healing, usually lasting 3 to 5 months, while occipitocervical fusion causes complete loss of occipitocervical flexion, extension and rotation. All these treatments have intrinsic disadvantages. Avoiding insufficient treatment, as is the case with the first 3 treatments, and excessive treatment, as is the case with occipitocervical fusion, is the main concern in the treatment of unstable atlas fracture, and therefore seeking a means of limited internal fixation has become a worthwhile subject of clinical study.

The development of C1 lateral mass-C2 pedicle screws in recent years has provided a technological possibility of using limited internal fixation for the treatment of unstable atlas fracture.

Materials and Methods

General Data

Throughout January 2001 to December 2004, 17 patients with atlas fracture were admitted, accounting for 5.1% of all cervical fractures of the same period. They included 12 male patients and 5 female patients ranging in age from 25 to 67 years with a mean of 42.5 years. Of the 17 cases of atlas fracture, 14 cases were classified as unstable atlas fracture; of them 11 patients underwent limited internal fixation.

Radiologic Evaluation

Means of determining atlas fracture and radiologic criteria: (1) The presence of fracture: radiograph films of the upper cervical spine may suggest fracture line and separation of the cervical arch; larger anteroposterior intertubercle space; open-mouth films may suggest larger interlateral mass space, or asymmetric interatlantoodonotoid space; bone window computed tomog-

From the *Orthopedic & Trauma-Surgery Department, East Hospital, Tongji University, Shanghai, People's Republic of China; †Orthopedic Department, The First Affiliated Hospital of Wenzhou Medical College, Zhejiang, People's Republic of China; and ‡Orthopedic Department, Changzheng Hospital, Second Military Medical University, Shanghai, People's Republic of China.

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The authors T.J. and L.L. have contributed equally for this manuscript.

Address correspondence and reprint requests to Tan Jun, MD, Orthopedic & Trauma-Surgery Department, East Hospital, Tongji University, Jimo Road #150, Shanghai, People's Republic of China; E-mail: dr.tan@139.com

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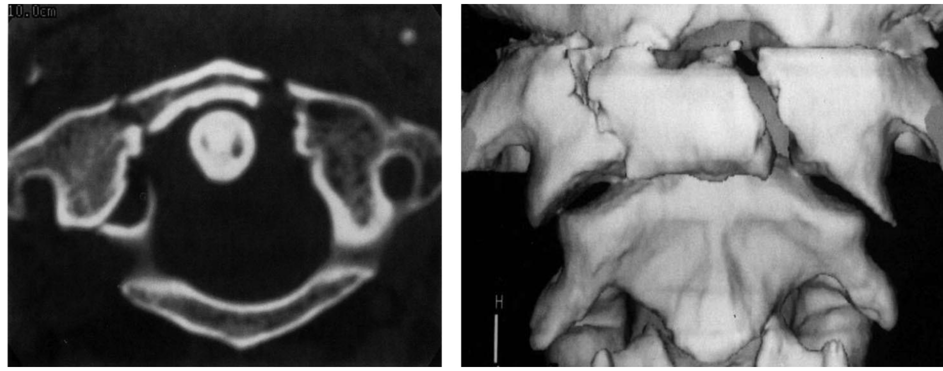

Figure 1. Fracture separation leads to axial instability, resulting in healing difficulty.

raphy (CT) scan may suggest fracture and detailed information of the fracture; (2) Judgment of axial instability: CT scan may suggest separation between the small joints or complete damage of the small joints, thus unable to provide axial load (Figure 1); (3) Judgment of rotation instability: open-mouth radiograph films may suggest the addition of the lateral edge of the C1 lateral mass and the lateral border of C2 exceeds 6.8 mm, indicating that the transverse ligament has lost control of the contralateral mass; CT measurement of transverse diameter and transverse separation of the fractured end; and particularly, the presence of avulsion fracture fragments in the medial small joints and evident antedisplacement of the anterior tubercle, both suggesting the existence of rotation instability.

Technical Objective, Mechanism and Method

Technical Objective. First of all, resume osseous anastomosis between the articular processes of C0–C1–C2; in case of fragmentation of the transverse ligament, resume stability of the sagittal plane between C1 and C2. The purpose of internal fixation is to resume anastomosis and maintain stability. The final stability is achieved by bone grafting fusion without causing occipitocervical fusion.

Technical Mechanism. Use C2 pedicle screws as the distal fixing point, and connect them with longitudinal rods and C1 lateral mass screws (Figure 2). On the basis of traction, further shorten separation between the unstable lateral masses by means of crosslink compression between the longitudinal rods. Finally, bone grafting fusion between C1 and C2 is performed to avoid dislocation between C1 and C2. This technique retains mobility of the occipitocervical junction.

Technical Method. C1 lateral mass screw technique + C2 pedicle screw technique + crosslink compression technique.

Operative Technique

Skull traction was performed in all patients, and operation was done only when the fracture was basically reduced. An abdominal framework of the cephlocervicothoracic plaster bed was prepared before surgery for use.

Operative Technique. Under general anesthesia a 7 cm posterior paramedian incision is made to expose the posterior structure of the upper cervical spine, including C1 posterior arch to the upper edge of the C3 lamina, and laterally to the external edge of the articular process. Make sure the position of C2 lateral mass; use the central point as the point of screw entry; dissect the soft tissue along the lateral border of upper C2 lamina with a nerve dissector to expose the initiation part of vertebral arch pedicle; the direction of screw entry can be obtained by dissect several millimeters of the upper margin and median margin of vertebral arch pedicle. Generally, use a 2.5 mm drill point to make a 20 mm depth under the guidance of the guide drill with the bit inclining by 25° to 30° and inwardly by 30° to 35°; implant the SUMMIT screw by 26 mm. Expose the atlas posterior arch bilaterally to the external side of dural capsule and dissect along the lower margin of posterior arch and external side of dural capsule to expose the posterior lateral mass; treat it slightly with a polishing drill; make a 10 mm depth with a 2.5 mm drill via the engagement of posterior lateral mass, tap it and implant the SUMMIT screw into a depth of 26 mm; connect the screws with the longitudinal rods and lock tightly; connect the rods with the transverse connector and exert pressure on the connector gradually; make a P-A fluoroscopic view *via* the mouth (Figures 3 and 4) to make sure that the separation between the lateral masses has been surely corrected, and finally lock the connector securely. Remove the cortex on the surface of the C1–C2 posterior structure and perform bone grafting fusion.

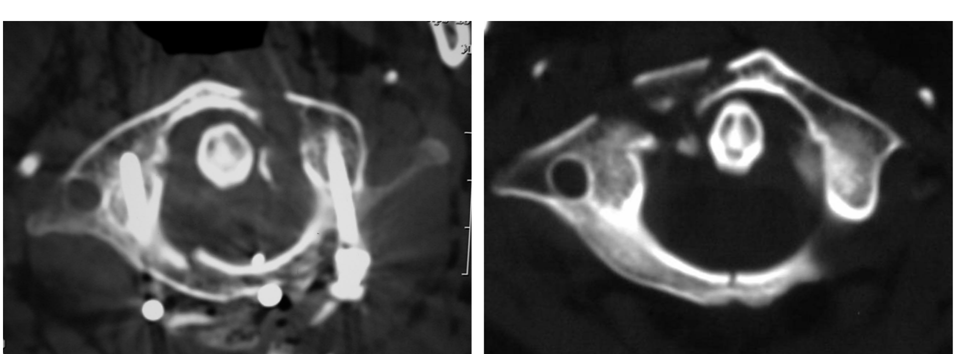

Figure 2. Another 2 cases: transverse ligament tear with teardrop fragment.

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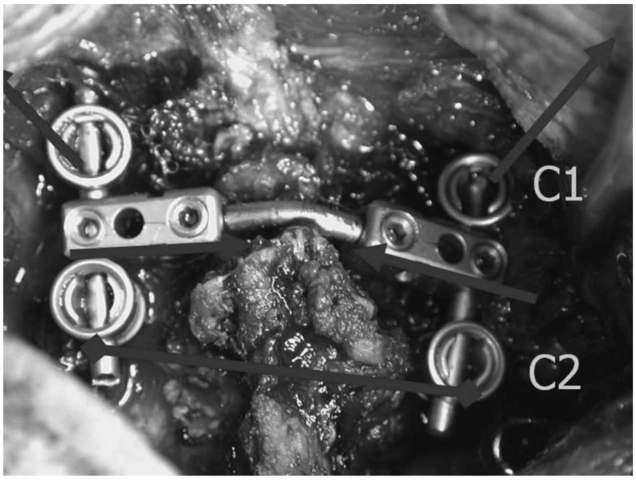

Figure 3. Mechanisms of fracture reduction technique: C2 pedicle screws serve as the supporting points of distal fixation, which are connected with bilateral C1 mass screws bilaterally by a longitudinal rod. On the basis of traction reduction, transverse connection between the longitudinal rods further shortens the separation between the unstable lateral masses.

Postoperative Treatment. Routine antibiotic therapy is instituted after surgery. In case the spinal cord is interfered with during the operation, intravenous drip of DXM and furosemide can be considered for 3 to 5 days. The patient is encouraged to ambulate when the cervical girth is fixed. Check-up is suggested 6 weeks after external fixation.

Results

Of the 11 cases, 6 cases were complicated with axial instability and rupture of the transverse ligament, 1 case with C2 laminal fracture, and the remaining 4 cases with axial instability.

The mean operation time of the 11 cases of this series was 124 minutes (90–176 minutes); mean blood loss was 432 mm (270–1200 mL); and mean fluoroscopic time was 18 seconds. All patients were able to be out of bed and move about 5 days after halo fixation. No deterioration of the spinal injury was observed. In 1 patient whose vertebral artery between C1 and C2 was injured by electric cauterization leading to rupture of the vertebral artery, in whom hemorrhage was controlled by outward tamponage of hemostatic gauze and fixation of the gauze onto the internal fixation with cement. No intracranial ischemic symptoms developed in this patient owing to postoperative close observation, complete drainage and delayed extubation.

The patients were discharged at a mean of 12 postoperative days, with a mean hospital stay of 18 days, and followed up after surgery for 6 to 40 months with a mean of 14 months. The lateral radiograph view of the cervical vertebra by 3-month follow-up showed that bony union was achieved in all patients, without evident instability. By 6-month follow-up, stiffness on flexion, extension and rotation of the cervical vertebra were observed, to our surprise, the range of rotation is over 90°.

Discussion

Uniqueness of Atlas Fracture

Unique Structure of the Atlas. The atlas is bilaterally prominent and wedge-shaped anteroposteriorly and transversely, forming an anastomotic relation with the homolateral occipital condyle and the superior articular surface of the atlas on the upper sagittal plane, and the bilateral superior articular surfaces of the atlas form a concentric ring with the bilateral occipital condyles on

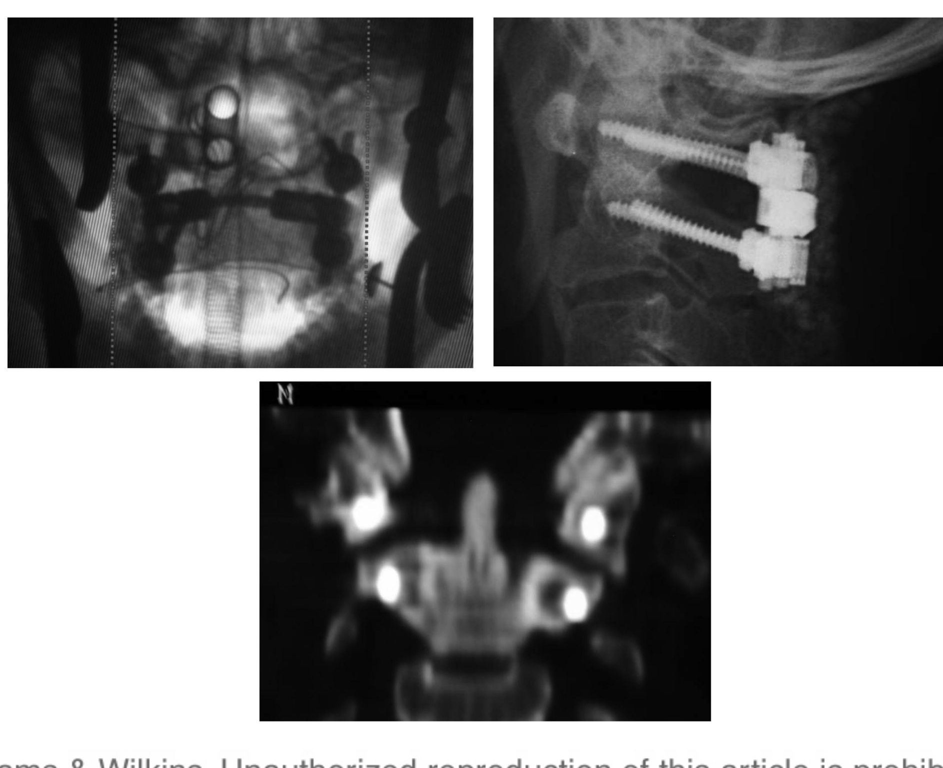

Figure 4. C1 Lateral mass-C2 pedicle screw technique.

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the coronary surface. Aanastomosis of the articular surface between the atlas and axis forms a slant angle medially, externally, and inferiorly.

Atlas Fracture and Separation Tendency. Axial violence is the destructive force of the atlas. The lateral masses are the firmest part of the atlas, the prominent anterior and posterior arches are also hard enough, and therefore fracture often occurs at relatively weak parts of the atlas. The existence of connecting tension between the atalntoodonotoid process and the occipital ligament and the tension from the external muscles and ligaments, the inferior-superior adjoining relation of the atlas, the wedge-shaped articular structure and the tubular meridians being larger than the inferior-superior structure, and the distinctive outward slant surface of the supporting surface of the atlas work together to produce the separation tendency of atlas fracture and poorer neurologic prognosis. This kind of C2 fracture was first reported by Jefferson in 1920.[1]

Atlantal Instability. Occipitoatlantal stability is usually maintained by anastomosis of the osseous structure, while simple osseous integrity between the atlas and the axis is not able to maintain stability; stability between the atlas and the axis also depends on integrity of the transverse ligament. Levine and Edward classifications are the generally accepted classification.[2] The key of understanding of this classification lies in recognizing the existence of axial conversion and rotation stability. Simple posterior arch fracture is the most common stable fracture, but unilateral or bilateral small joint freedom may constitute instability of C injury of AO (compression, extension and rotation instability). Reduction by pulling is the basis of traction treatment.

Characteristics of Prior Treatment

Short-term neurologic complication is usually not overt in atlantal instability where fracture does not exert direct compression on the spinal cord and therefore immediate decompression is not necessary; indirect reduction by axial traction can be considered by using cephlocervicothoracic plaster fixation after traction. Many clinical surgeons are optimistic about this kind of traction therapy. The theoretical basis of this treatment is that bony union can be achieved by conservative therapy such as axial traction to reduce fracture fissure in most cases where there is no rotation instability despite the existence of separation, and separation of the lateral masses is not significant. In the early stage of traction, a slightly flexed modality can be used to increase tension of the transverse ligament and close the separated lateral masses. In this therapeutic modality, stability is expected through long bed-ridden confinement or external fixation; or limited operation is performed as a means of compensation in the late stage. But as external fixation has a relatively poor control over the upper cervical vertebra, the rate of healing is low and the course of treatment is relatively long. As a result, there are more complications and the therapeutic efficacy is not desirable. In some patients, especially those with relatively large fracture separation and atlantal instability of evident consolidation, surgical intervention is still needed because of pain and limited mobility arising from residue atlantal instability after conservative treatment. For this reason, more researchers tend to advocate early surgical intervention of patients with instability of consolidation, which, they believe, is beneficial to reduction and healing of the fracture and restoration of atlantal stability.[3–7]

To achieve a more definite prognosis, surgical intervention is suggestive to shorten the course of external fixation and reduce dependence on it. The effect of occipitocervical fusion on the reconsturction of stability is unquestionable; the problem is that the cervical vertebra may lose much of mobility after fusion, which is contradictory to the therapeutic principle of spinal surgery.

Mechanisms and Characteristics of Limited Internal Fixation

The basic pointer in treating atlantal instability is to maintain the space arrangement of normal stability between the atlantal processes and the sagittal sequence between the cervical vertebrae. Advances in technology and instrumentation for internal fixation of the upper cervical vertebra render it possible to reconstruct occipitocervical stability earlier and more definitely without losing physiologic activity between the cervical vertebrae, and at the same time to shorten the bed-ridden time and the time of conservative treatment, and save medical expenses and medical resources as well. At present there are at least 5 technical approaches available to achieve the above-mentioned goals.

Technique 1. C1–C2 postcervical approach using the transarticular process screw technique: As this technique has been reported in many studies of the literature,[4,8] we are not going to describe it in details. This technique has a good limiting effect on rotation of the cervicle vertebrae but has no significant limiting effect on extension. It is not affected by posterior arch fracture, though displacement of the lateral masses has significant influence on the effectiveness and safety of fixation. As intraoperative fixation does not play a direct role in reduction, good reduction by preoperative traction is the prerequisite of operation. The advantage of this technique is that bone grafting fusion can be done simultaneously.

Technique 2. C1–C2 anterior approach using the transarticular process screw fixation: The characteristics of this technique are the same as those of technique 1. It is comparatively safe because it is not necessary to turn over the body and expose the wounded vertebrae. The problem is that it is impossible to perform first-stage bone grafting fusion specific to C1–C2 instability. C1–C2 anterior or posterior approach using the transarticular process screw fixation plus stainless wire cerclage of the C1–C2 laminas can greatly enhance strength of internal fixation at the extension level.

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Technique 3. Anterior approach using the transoral lateral mass fixation: Ruf *et al*[9] first reported this technique in 2005. They implanted a steel plate or connecting bar between the screws and exerted a pressure between the screws bilaterally to directly reduce the separated lateral masses in 6 cases of unstable Jefferson fracture complicated with transverse ligament rupture. The authors believed that the outcome would be better if the position of the lateral masses is a bit anterior and fore arm of anterior reduction is short. Good reduction is beneficial to restoring the normal connection between the atlantoaxial joint and the atlanto-occipital joint without sacrificing atlantoaxial rotation. They also reported through observation that there was no postoperative atlantoaxial instability in these patients, and thus deduced that, other than the transverse ligament, atlantoaxial stability largely depends on the other structures such as the articular capsule and alar ligaments. But as the number of cases they reported is small, their conclusion remains to be further testified. Theoretically, simple reduction fixation of the C1 lateral masses is unable to deal with complicated existence of atantoaxial instability and is only indicated for stable atlas fracture. But stable atlas fracture can be managed successfully by external fixation without surgical treatment.

Technique 4. Anterior approach using transoropharyngeal atlantoaxial reduction plate has been confirmed as good as combined use of Magerl and Brooks fixations in biodynamic experiments and preliminary clinical trials.

Technique 5. C1 Lateral mass-C2 pedicle screws and crosslink compression fixation as is described in the present article. As this technique is able to control centrifugal separation of the articular processes and comprehensive ability of stability from rotation instability, and at the same time fix the posterior arch and bone grafting fusion, it would prove to be a therapeutic option for instable atlas fracture. The key of the technique is C1 lateral mass-C2 pedicle screws manipulation, which requires high operative skills. Our ample experience in fixation strength of the C1 lateral mass-C2 pedicle screws, and biodynamics and anatomy of C2 pedicle screw entry has testified the feasibility, safety and fixation strength of the 2 methods.[10–13] Harm *et al*[14] proposed a similar posterior approach using C1 lateral mass-C2 pedicle screws technique. Their technique is different from ours in that they did not use cross compression fixation. Cross compression in our technique is able to enhance prompt reduction of the displaced lateral masses and strengthen the structure of internal fixation, especially rotation stability so as to achieve firm anatomic reduction and secure stability. Successful use of the "physiologic repair" technique for short segments in severe unstable Jefferson fracture may change the conventional therapeutic conception.

Prospects

In the absence of rotation instability, physiologic repair can be achieved technically by atlantoaxial fusion. Only when force arm of flexion between the atlas and the axis is relatively large, the rate of fusion may be affected. At present, there is no internal fixation instrumentation available that is specific to cross compression between the atlas and the axis and designed according to the relevant conception.

■ Key Points

- Osteosynthesis of the atlas are carried by means of C1 lateral mass screws and C2 pedicle screws.
- Crosslink compression fixation technique are done for reduction the separation of atlas fracture.
- C1–C2 fusion with posterior bone grafting was performed.

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