One stage anterior-posterior approach for traumatic atlantoaxial instability combined with subaxial cervical spinal cord injury

WANG Chang-sheng, LIU Mou-jun, LIN Jian-hua*, XU Wei-hong and LUO Hong-bin

Abstract
Objectives: To explore the clinical features of traumatic atlantoaxial instability combined with subaxial cervical spinal cord injury (CSCI), and to analyze the feasibility, indication and therapeutic effects of anterior-posterior approach in such cases.
Methods: From March 2004 to September 2009, 16 cases with this trauma were admitted and surgically treated in our department. Before surgery, skull traction was performed. Posterior atlantoaxial pedicle screw internal fixation and bone graft fusion were conducted to manage traumatic atlantoaxial instability. As for subaxial CSCI, anterior cervical corpectomy or discectomy decompression, bone grafting and internal fixation with steel plates were applied.
Results: All operations were successful. The average operation time was 3 hours and operative blood loss 400 ml. Satisfactory reduction of both the upper and lower cervical spine and complete decompression were achieved. All patients were followed up for 12 to 36 months. Their clinical symptoms were improved by various levels. The Japanese Orthopaedic Association (JOA) scores ranged from 10 to 16 one year postoperatively, 13.95±2.06 on average (improvement rate=70.10%). X-rays, spiral CT and MRI confirmed normal cervical alignments, complete decompression and fine implants’ position. There was no breakage or loosening of screws, nor exodus of titanium mesh or implanted bone blocks. The grafted bone achieved fusion 3-6 months postoperatively and no atlantoaxial instability was observed.
Conclusions: Traumatic atlantoaxial instability may combine with subaxial CSCI, misdiagnosis of which should be especially alerted and avoided. For severe cases, one stage anterior-posterior approach to decompress the upper and lower cervical spine, together with reposition, bone grafting and fusion, as well as internal fixation can immediately restore the normal alignments and stability of the cervical spine and effectively improve the spinal nervous function, thus being an ideal approach.

Key words: Atlanto-axial joint; Cervical vertebrae; Spinal injuries; Cervicoplasty

Injuries to the lower cervical spine are common in clinic. About 40% of them would accompany functional impairment of the spinal cord and another 10%, though combined with nerve function impairment, will not present with abnormal X-ray findings. Injuries to the atlantoaxial vertebrae, or upper cervical spine as we usually say, have attracted lots of concerns in recent years. Because the caliber of the atlantoaxial spinal canal is relatively large, the nerve is much more likely to be injured compared with the lower cervical spine. However, under the situation that injuries occur both to the upper and lower cervical spine, especially when routine X-ray examination does not reveal abnormal signs or the nerve injury is mild, misdiagnosis easily happens. This kind of cases is seldom reported in the literature. From March 2004 to September 2009, 16 cases of traumatic atlantoaxial instability combined with subaxial cervical spinal cord injury (CSCI) were successfully treated in our department by one stage anterior-posterior approach, reported as follows.

METHODS

General data
This study consisted of 16 patients, 10 males and 6 females, aged 45 to 66 years, mean 56.8 years. The
injury causes were traffic accident (8 cases), falling from a height (4 cases), falling down onto the flat ground (2 cases) and hit by heavy objects (2 cases). Traumatic atlantoaxial instability included atlas fracture with atlantoaxial instability (2 cases), fresh odontoid fracture with atlantoaxial dislocation (9 cases: 8 type II C and 1 type III obvious fracture displacement based on Grauer et al’s modified Anderson-D’Alonzo classification), transverse ligament rupture with atlantoaxial dislocation (3 cases), and atlantoaxial dislocation caused by trauma to the free odontoid (2 cases). Lower CSCI were composed of 11 cervical hyperextension injury (9 having history of basic cervical spinal diseases and 2 having segmental ossification of the cervical posterior longitudinal ligament), 3 traumatic cervical disc hernia with spinal cord compression injury, and 2 subaxial cervical vertebra fracture dislocation (AO classification). All the 16 cases were acute injuries (duration from injury to admission within 3-48 hours, mean 16.5 hours). For patients transferred from other hospitals or the emergency department, 2 cases of upper and 3 cases of lower cervical spinal injuries were misdiagnosed.

Before injury, all patients had no history of obvious numbness or weakness of the limb, and at admission they all presented with different levels of pain, stiffness, limited mobility of the cervical spine and incomplete paralysis of the limb. According to Japanese Orthopaedic Association (JOA) scoring system (17 scores), the preoperative spinal cord nervous function scored 4-12, 6.80±2.20 on average. All patients received cervical anteroposterior, lateral and open-mouth X-ray, occipitocervical spiral CT 3D reconstruction and cervical MRI under the accompanying of medical staff. Some patients underwent additional cervical hyperextension and hyperflexion radiography. Cervical kinematic X-ray films and CT 3D reconstruction showed atlantoaxial instability, subaxial cervical fracture displacement, hyperplasy and degeneration, posterior longitudinal ligament ossification, etc, while MRI revealed different levels of depression of the upper and lower cervical spinal cord in all patients. Among them 6 had signal change of the upper cervical spinal cord and 16 showed high signals of the lower cervical spinal cord due to hemorrhage or edema.

Treatment

Patients with acute spinal cord injuries (within 8 hours) received high-dose methylprednisolone pulse therapy. All patients underwent skull traction as early as possible after their admission. Based on the displacement of odontoid process, upper and lower cervical spine, we timely adjusted the position, direction and weight of traction on the head and neck region. Bedside radiography was applied to observe the real-time reduction and during the whole process patients’ vital signs and spinal cord nerve function were closely monitored. Twelve cases received surgical treatment 72 hours after injury.

All patients were anesthetized by bronchoscope-guided nasotracheal intubation at conscious state. Cervical posterior approach was firstly conducted, with the patient in prone position and his forehead and face on a headframe. During skull traction, the direction was timely adjusted to find a proper position for the atlantoaxial vertebrae under the monitoring of a C-arm fluoroscopic X-ray machine (Arcadis orbic 3D, Siemens AG, Germany). A longitudinal incision was made on the midline of the posterior neck to expose the basilar part of the occipital bone, posterior arches of C1 and C2, and then C1 and C2 pedicle screws were respectively placed and assembled with rods following Xiao et al’s and Resnick et al’s methods. Intraoperatively, the curvature of the connecting rod can be adjusted to further reposition those failed to achieve satisfactory reduction following atlantoaxial dislocation. For patients with unstable atlas fractures, a cross bar was added to increase compression, separate and reposition the C1 lateral mass. After fixation, autologous iliac bone grafting was carried out in the posterior arches of atlas, axis and spinous process of axis. One case of lower cervical fracture-dislocation, who failed in the unlocking and reduction of the small articular process by preoperative skull traction, received the unlocking and reduction procedures again during upper cervical posterior approach.

After posterior surgery, maintain the anesthesia and skull traction, protect the head and neck, turn the patient to supine position along the axis line, make a transverse or oblique incision over the right anterior cervical spine, and conduct cervical anterior decompression (discectomy or corpectomy), autologous iliac bone grafting (titanium cage filled with autologous bone), and anterior self-locking titanium plate fixation. Intraoperatively, resect the posterior longitudinal ligament routinely, expose the dura, and perform complete decompression.
Skull traction was removed immediately after operation. Six hours later, patients can wear neck collar or cervical gear in Fowler position. The respiration, heart beat and function of spinal cord was closely monitored. If spinal cord neurological function permitting, rehabilitation care should begin as soon as possible. The external fixator was removed at 12 weeks.

**Postoperative follow-up and outcome assessment**

After operation patients were followed up regularly. They were reexamined every three month within one year time and twice a year after then. During the follow-up, anterior, lateral, open-mouth and kinematic radiography, as well as cervical CT scan and MRI were performed. The evaluation for nervous function was based on the JOA scores one year before and after operation. The recovery rate was calculated as follows:

\[
\text{Recovery rate} = \frac{(\text{scores at follow-up} - \text{scores at admission})}{(17 - \text{scores at admission})} \times 100\%
\]

**RESULTS**

All patients achieved complete or basic atlantoaxial reduction after skull traction. Anterior-posterior approach was successfully conducted and the spinal cord injury was not aggravated. In posterior approach, there were 32 C2 and 32 C1 pedicle screws implanted. The operation time and operative blood loss averaged 1.5 hours and 300 ml, respectively. The location of screws was satisfactory. They did not penetrate into the spinal canal or injure the vertebral artery and spinal cord. In anterior approach, thorough undercutting decompression was achieved. The average operation time was 1.5 hours and operative blood loss was 100 ml. The titanium plate, screws and titanium mesh, as well as bone graft obtained a good position. Follow-up lasted for 12-36 months. After patients discharged from hospital, assessment of nervous function and radiological examination were regularly carried out. Results showed that cervical alignments were normal and implants were all in fine position. No breakage or loosening of steel plates or screws, nor exodus of titanium mesh and bone grafts was found. The bone grafts achieved fusion 3-6 months after operation and the atlantoaxial vertebrae were stable. All patients obtained various levels of improved spinal cord function. The JOA scores ranged from 10 to 16 one year postoperatively, 13.95±2.06 on average. The improvement rate was 70.10% (Figure 1).

**DISCUSSION**

**Clinical features of traumatic atlantoaxial instability combined with subaxial CSCI**

Traumatic atlantoaxial instability refers to traumatic injuries to the atlas, axis, intervertebral joints and connecting ligaments, resulting in dysfunction and loss of stability, moreover, atlantoaxial dislocation or subluxation. It can early accompany or later present with spinal cord or nerve root stimulation and compression. According to the different injured structures, it can be divided into ligamental structure instability like injury to the transverse ligament of atlas, and bone structure instability such as fractures of the...
arch of atlas, odontoid and free odontoid. Lower cervical spinal injury, which can be caused by various violence especially hyperextension in clinic, is pretty common in cervical injury. Patients with cervical degeneration or primary cervical spinal canal stenosis are at a high risk of concomitant spinal cord injury.

Combined injury both to upper and lower cervical spine caused by the same violence acting on the head and neck is rare in clinic. Korre et al\(^5\) and Li et al\(^6\) also reported a very low incidence of this kind of injury. The injury mechanisms are not clear now, maybe associated with traumatic violence conduction, some basic diseases like cervical degenerative change and developmental spinal stenosis, and the particular position of the head at the moment of injury.

This series of patients has some clinical features. (1) The patients were mainly middle-aged or elder people (mean age >45 years old). This may be due to the degeneration and proliferation of their cervical vertebrae, great decrease of the lower cervical activities, and compensatory increase of the atlantoaxial joint activities, thus easily prone to atlantoaxial instability and lower cervical spinal injury under violence. (2) Many patients once suffered from some basic cervical diseases such as odontoid process hypoplasia or odontoid ossicle lesion, and thus external force can easily cause atlantoaxial dislocation. Besides, the lower cervical spine is frequently exposed to some basic diseases like ossification of cervical posterior longitudinal ligament, developmental spinal stenosis, ankylosing spondylitis, cervical instability, etc. Because of pathological changes of these segments, including disc degeneration, thinning of ligament structure, etc, the cervical physiological line may break down or there exists a biomechanically weak area.\(^7\) As a result, even a small stress conduction can easily induce lower cervical spinal cord injury and compression. (3) Nerve injury mostly occurs in the lower cervical spinal cord. The atlas canal has a large volume and the sagittal diameter is normally >2 cm, with odontoid process, spinal cord and compensatory space respectively in the anterior, middle and posterior 1/3 of the canal. If the traumatic atlantoaxial dislocation has not involved the middle 1/3 of the canal, spinal cord compression will not present. As for the lower cervical spine with basic pathological changes, due to its obviously smaller inner diameter, external force can easily lead to compression and injury to the spinal cord. (4) Hyperextension injury accounts for the majority of lower cervical spinal injury. Because the patients are middle-aged or elderly and have cervical spinal stenosis, hyperextension is likely to cause anterioposterior compression injury. (5) Misdiagnosis frequently happens. In patients with obvious subaxial cervical fracture-dislocation and tetraplegia, trauma-caused instability of the atlantoaxial ligament or bone structure is usually ignored because the clinicians are insufficient of experience and careless in reading radiographs, or they focus too much on the lower cervical spinal injury due to the lack of cervical kinematic films and CT 3D reconstruction. On the contrary, atlantoaxial fracture-dislocation has distinguished imaging characteristics, while subaxial cervical hyperextension injury shows no apparent abnormality by routine X-ray examination, thus easily to be misdiagnosed and getting worse, especially at emergency admission.

**Feasibility of anterior-posterior approach**

The surgical strategies for atlantoaxial instability, including anterior and posterior approaches, can be properly chosen according to etiopathogenesis and dynamic clinical classification.\(^8\) Those caused by type IIB odontoid process fracture and Hangman’s fracture can be managed by anterior surgical approach. In the recent ten years, the treatment by posterior C1 and C2 pedicle screw internal fixation has been world-widely accepted and applied.\(^9\)\(^-\)\(^11\) This technique has the characteristics of simple procedures, solid fixation, good biomechanical strength and a wide clinical application compared with the anterior approach. It can be used to manage type IIC odontoid process fracture, type IIB odontoid process fracture with severe displacement and poor reduction, old odontoid process fracture, transverse ligament injury, odontoid abnormality, rheumatoid arthritis, atlas fracture and atlantoaxial instability due to iatrogenic upper cervical spinal injury, etc. Moreover, it has some incomparable advantages, compared with other posterior methods like Gallie’s technique, Brooks’s method, Appofix system and Magerl technique. While subaxial cervical anterior corpectomy or discectomy decompression, bone grafting and plate internal fixation are the classic surgeries for lower cervical spinal diseases that have been already widely acknowledged and mastered by surgeons in the spinal surgery department.
With the maturation of surgical skills and team work, continuous improvement and updating of operation instruments & implants, the operation time and blood loss in one stage upper and lower cervical anterior-posterior approach can be successfully controlled within a satisfactory extent and the surgical invasion is largely decreased. Besides, the close cooperation among related departments, including department of anesthesiology, ICU, etc, significantly increases the peri- and intraoperative safety, and most patients can tolerate the operation. In this study, the average operation time and blood loss was respectively 3 hours and 400 ml, and all patients passed the perioperative period uneventfully.

Adaptive diseases of one stage anterior-posterior surgical approach

The application of anterior-posterior surgical approach on traumatic atlantoaxial instability combined with lower CSCI should depend on individual conditions. Detailed injury conditions of the upper and lower cervical vertebrae are very important for making proper treatment plans for each individual. We suggest that one stage anterior-posterior surgical approach be the first choice for patients who have traumatic atlantoaxial instability, dislocation combined with lower cervical vertebra injury, spinal cord involved-intervertebral disc injury and neurological dysfunction, and failed to obtain stability by traction. But for those only with traumatic atlantoaxial instability or dislocation who achieved stable reduction by traction, conservative treatment is considerable. Moreover, for patients experience mild lower CSCI or insignificant damaged stability of the lower cervical spine, or elder patients with various concomitant diseases who may cannot tolerate surgeries, conservative treatments are treatment options.

Experience in the diagnosis and treatment of traumatic atlantoaxial instability combined with subaxial CSCI and analysis on the therapeutic effects

Traumas to the cervical vertebra can induce transient dislocation, which may reestablish normal alignment due to contraction of the surrounding muscles and ligaments. Therefore, patients with cervical spinal injury need to take thorough physical examination and imaging test, including anterior, lateral and open-mouth X-rays, cervical 3D CT reconstruction and MRI. Under the protection and monitoring of medical staff, kinematic X-ray images should be obtained to confirm the injury condition of the upper and lower cervical vertebrae and spinal cord, excluding cervical instability and occult injuries to avoid misdiagnosis and delayed treatment.

Due to its frequent combination with CSCI, surgical interventions in time are very important to save the spinal cord and avoid aggravating secondary lesion. Operation should be conducted within 72 hours after injury, which could decompress the spinal cord and recover the spinal nervous function maximally. However, since the patients are mostly elderly with acute injury to multiple segments, appropriate assessment of the general condition and proper preoperative treatment are crucial and should not be ignored. In this series, the operations were delayed in 4 cases because of the management of concomitant diseases.

Patients with traumatic atlantoaxial dislocation, especially acute injury, mostly can obtain complete or basic reduction after traction. Therefore, after admission skull traction should be conducted as soon as possible. During the process, spinal nervous function and vital signs should be closely monitored, and if they change, the traction direction and weight need to be timely adjusted. Anesthesia by transnasal fiberoptic bronchoscope intubation in conscious state is proposed because this can avoid aggravating spinal cord injury due to head or neck over-back-extension. Skull traction needs to be retained during the whole operation and positional change, by which head and neck stability can be guaranteed to avoid accidents. Posterior surgeries can be firstly conducted to stabilize the atlantoaxial vertebra and protect the spinal cord in positional change. For patients who have dislocation and interlocking of the articular process and fail in preoperative traction, posterior approach can be simultaneously conducted. As for the anterior approach, because most patients are associated with basic diseases such as cervical spinal stenosis, surgeons should pay more attention to thorough decompression, which can be achieved by routine potential decompression, removal of the posterior longitudinal ligament and exposure of the dura.

The 16 patients in this study gained satisfactory or basic reduction after preoperative skull traction followed by one stage anterior-posterior surgical approach (surgical interventions were performed within 72 hours
after injury in 12 cases). Atlantoaxial dislocation was well reduced and fixed, the lower cervical spinal cord was completely compressed and the postoperative spinal cord function recovered to various extents.

REFERENCES


(Received December 11, 2010)