Chapter 41
Innovative Internal Fixation for Cervical Spine Fractures

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The increase in the number of available internal fixation devices for the cervical spine has promoted innovative stabilization of traumatic instability of the craniocervical junction. Traumatic injuries involving the craniocervical junction vary widely because of the complex osseous and ligamentous anatomy. These injuries can be purely ligamentous, such as occipitocervical dislocation, or can include single or multiple bony levels. Rare, however, are occasions of isolated osseous fractures without ligamentous damage. The extent of ligamentous damage usually dictates the presence of instability and the need for surgical fixation.

The complexity of the craniocervical junction mainly reflects the translational anatomy between the occiput and cervical spine. This translation enables great mobility in several planes and complements the sensory systems. The price for this mobility is vulnerability to traumatic injury of the craniocervical junction. The decision tree for treating these injuries includes the need to preserve this mobility, if possible. The following discussion highlights recent, innovative techniques for stabilizing traumatic cervical injuries while preserving normal physiological function.

OCCIPITOCERVICAL INSTABILITY

Occipitocervical dislocation injuries are relatively rare and account for approximately 1% of all injuries involving the cervical spine (12). However, these injuries are often severe and therefore tend to be fatal. In fact, they are thought to be underdiagnosed. Multiple ligaments are responsible for structural support at the occipitocervical junction. The anterior and posterior atlantooccipital membranes attach the atlas to the occiput. The tectorial, alar, and apical ligaments attach the axis to the occiput. Finally, the transverse and atlanto-alar ligaments attach the atlas to the axis. The extent of damage to these ligaments determines the type of fixation required.

There are a variety of ways to determine instability at the occipitoatlantal or atlantoaxial joints. Plain radiography is usually the first-line imaging modality. Findings related to occipitoatlantal translation, lateral atlas displacement, or atlantoaxial translation can raise suspicions of instability (7, 14). Computed tomography (CT) improves definition of these articulations and can also detect rotational subluxation. Magnetic resonance imaging (MRI) can help determine ligamentous injury, especially of the transverse atlantal ligament (3). However, it should be used with caution as the sole modality for determining stability because it is highly sensitive to any type of soft tissue injury (10).

CASE ILLUSTRATIONS

Occipitocervical Fixation

A 53-year-old man was admitted through our Level I trauma service after being ejected from an automobile during a motor vehicle accident. He was intubated at the scene. On arrival, his score on the Glasgow Coma Scale was 5T. He withdrew his extremities stronger on the right than on the left. Plain radiographs in the trauma room demonstrated significant distraction at both the occipitoatlantal and atlantoaxial joints (Fig. 41.1A). Because of the obvious instability at these levels, he was placed in an external halo orthosis. During the next few days, he regained consciousness but still had significant left-sided hemiparesis. He then was taken to the operating room and underwent successful occipitocervical fixation to the third cervical level. A Steinmann pin and Songer cables were used as instrumentation, and a hip autograft was used to facilitate fusion (Fig. 41.1B),, as described elsewhere (1, 2). The patient recovered with only slight weakness in his left arm. Three months after surgery, follow-up imaging confirmed the presence of good fusion.

Occipitoatlantal Fixation

A 31-year-old woman involved in a motor vehicle accident was admitted through our trauma service. She was neurologically intact but complained of severe suboccipital neck pain. CT scans showed bilateral occipital condylar fractures with significant displacement (Fig. 41.2A). The base of the clivus was also fractured and clearly unstable. This type of fracture has been treated with rigid immobilization, but we believed that the degree of instability in her case warranted internal fixation (11,15). The lack of soft tissue edema at the atlantoaxial joint suggested that it was stable. She therefore underwent fixation for her occipitoatlantal instability.

At surgery, the absence of laxity at the atlantoaxial interface further confirmed the stability of that level. A screw-rod construct was placed from the occiput to the atlas bilaterally. Screws were placed in the occipital keel and attached by titanium rods to lateral mass screws placed into the atlas (Fig. 41.2B). Autograft derived from the iliac crest was used as a fusion construct. After surgery, she was placed in a rigid collar. Six weeks after surgery, she showed signs of developing a good fusion (Fig. 41.2C).

A 17-year-old boy involved in a high-speed automobile accident was admitted through our Level I trauma service. He was neurologically intact but complained of severe suboccipital neck pain. A CT scan showed significant occipitoatlantal distraction without fracture (Fig. 41.3A), and he was placed in halo immobilization. MRI of his cervical spine showed gross ligamentous disruption at the occipitoatlantal joints but no signs of instability at the atlantoaxial joints. Recently designed and biomechanically tested transarticular screws were used for internal fixation of the occipitoatlantal joints (5, 8). Autologous hip autograft was wired in place between the occiput and posterior arch of the atlas to facilitate fusion. After surgery, his construct was stable, and he wore a rigid collar for 3 months. One year after surgery, he was neurologically intact and pain free with a solid fusion (Fig. 41.3B).

Atlantoaxial Fixation and Image Guidance

A 45-year-old man was admitted through our Level I trauma service after a motor vehicle accident. He was intubated at the scene and had moderate weakness of his left arm and leg. Radiographs obtained in the trauma room showed a significant bilateral distraction injury at the atlantoaxial joint and an avulsion fracture of the anterior arch of the atlas (Fig. 41.4A). The degree of distraction, as measured on a CT scan, was consistent with instability (6). The amount of distraction precluded the use of transarticular screws; therefore, the decision was made to reduce and fixate the injury with an atlantoaxial screw-rod construct (9).

Biomechanically, this construct is as rigid as the more common transarticular screw technique (13). Image guidance was also used to facilitate appropriate placement of the screw. Polyaxial titanium screws were inserted bilaterally into the lateral masses of the atlas and into the pedicles of the axis. After the distraction was reduced, the screws were fixated with a titanium rod (Fig. 41.4B). An autologous hip graft was wired into place to facilitate fusion using the technique described by Dickman et al.(4) After surgery, the patient's neurologic status improved, and he developed a solid fusion (Fig. 41.4C).

A 74-year-old man fell from a tree during a hunting trip and suffered a minimally displaced, type II odontoid fracture. Initially, he was treated with halo immobilization. Upright and supine lateral radiographs obtained while he wore the halo brace showed instability. The decision was made to treat him with internal fixation using atlantoaxial transarticular screws. Because the partes interarticularis of the axis were relatively narrow, intraoperative image-guidance (Stealth station, Medtronic SNT, Louisville, CO) was used to avoid injury to the vertebral artery (Fig. 41.5). Fusion was facilitated by wiring an autologous hip graft into the atlantoaxial interspinous space. His vertebral arteries were uninjured, and he developed an excellent fusion.

CONCLUSION

Numerous options are available for internal fixation of the craniocervical junction after traumatic instability. New innovations in both instrumentation and imaging now often allow mobility to be preserved at the atlantoaxial joint. Image guidance facilitates performing procedures for internal fixation and increases the safety of surgery in patients with abnormal anatomical configurations.

REFERENCES

1. Apostolides PJ, Dickman CA, Golfinos JG, et al.: Threaded Steinmann pin fusion of the craniovertebral junction. **Spine** 21:1630–1637, 1996.

2. Apostolides PJ, Karahalios DG, Yapp RA, et al.: Use of the BendMeister rod bender for occipitocervical fusion: Technical note. **Neurosurgery** 43:389–390, 1998.

3. Dickman CA, Greene KA, Sonntag VK: Injuries involving the transverse atlantal ligament: classification and treatment guidelines based upon experience with 39 injuries. **Neurosurgery** 38:44–50, 1996.

4. Dickman CA, Sonntag VK, Papadopoulos SM, et al.: The interspinous method of posterior atlantoaxial arthrodesis. **J Neurosurg** 74:190–198, 1991.

5. Gonzalez LF, Crawford NR, Chamberlain RH, et al. Craniovertebral junction fixation with transarticular screws: Biomechanical analysis of a novel technique. **J Neurosurg Spine** 98:202–209, 2003.

6. Gonzalez LF, Fiorella D, Crawford NR, et al. Vertical atlantoaxial distraction injuries: radiological criteria and clinical implications. **J Neurosurg Spine** 1:273–280, 2004.

7. Greene KA, Dickman CA, Marciano FF, et al. Acute axis fractures: Analysis of management and outcome in 340 consecutive cases. **Spine** 22:1843–1852, 1997.

8. Grob D: Transarticular screw fixation for atlanto-occipital dislocation. **Spine** 26:703–707, 2001.

9. Harms J, Melcher RP: Posterior C1-C2 fusion with polyaxial screw and rod fixation. **Spine** 26:2467–2471, 2001.

10. Horn EM, Lekovic GP, Feiz-Erfan I, et al.: Cervical magnetic resonance imaging abnormalities not predictive of cervical spine instability in traumatically injured patients. **J Neurosurg Spine** 1:39–42, 2004.

11. Payer M, Delavelle J: Bilateral occipital condylar fracture: Case report about successful treatment with SOMI brace. **J Clin Neurosci** 11:211–214, 2004.

12. Powers B, Miller MD, Kramer RS, et al.: Traumatic anterior atlanto-occipital dislocation. **Neurosurgery** 4:12–17, 1979.

13. Puttlitz CM, Melcher RP, Kleinstueck FS, et al.: Stability analysis of craniovertebral junction fixation techniques. **J Bone Joint Surg Am** 86A:561–568, 2004.

14. Spence KF Jr, Decker S, Sell KW: Bursting atlantal fracture associated with rupture of the transverse ligament. **J Bone Joint Surg Am** 52A:543–549, 1970.

15. Tanabe M, Watanabe T, Matsumoto S, et al.: Avulsion fracture of the anterior half of the foramen magnum involving the bilateral occipital condyles and the inferior clivus: Case report. **Neurol Med Chir (Tokyo)** 39:358–361, 1999.

FIG. 41.1 *A*, Lateral radiograph shows significant occipitoatlantal and atlantoaxial distraction injuries. *B*, Intraoperative photograph shows the placement of the Steinmann pin and Songer cable in the occipitocervical fixation construct.

FIG. 41.2*A*, Axial (*upper left*) and reformatted sagittal computed tomographic images show bilateral occipital condylar fractures. *B*, Intraoperative photograph shows the occipitoatlantal fusion construct. *C*, Lateral radiograph obtained 6 weeks after surgery shows early signs of fusion.

FIG. 41.3*A*, Reformatted coronal computed tomographic image shows occipitoatlantal dislocation. *B*, Lateral radiograph obtained 1 year after surgery shows excellent alignment of the occipito-atlantal screws and a solid fusion.

FIG. 41.4*A*, Lateral radiograph shows a severe atlantoaxial distraction injury and avulsion fracture of the atlas. *B*, Intraoperative photograph of fixation constructs. *C*, Postoperative lateral radiograph confirms that the screws placed in the lateral masses of the atlas and in the pedicles of the axis provided excellent reduction and fixation.

FIG. 41.5 Stealth station images of the trajectory view for placement of atlantoaxial transarticular screws.