Occipitoatlantal dislocation, a well-documented devastating injury, is usually fatal. Atlantoaxial dislocation and OAD appear to share many similarities. In both cases, an enormous applied distractive energy pulls the head vertically. This energy separates the skull base from the atlas in the case of an OAD or widens the gap between the atlas and axis in the case of a vertical AAD. How the CVJ is distracted at two different levels by the same type of mechanism is unknown as is the point where the energy of the injurious force is absorbed. We present two clinical examples of this combined injury and discuss treatment options.

Case Reports

Case 1

This 25-year-old woman involved in a motor vehicle accident arrived at the emergency department in poor neurological condition (Glasgow Coma Scale Score 4). Cervical CT scanning revealed that the spaces rostral and caudal to C-1 were widened (Fig. 1). This separation elongated the third portion of the VA. Such an injury is extremely unstable and, as illustrated by this case, fatal. Extensive distraction of the VA in a fixed segment that does not tolerate elongation presumably caused arterial dissection and led to the patient’s death a few hours after admission.

Case 2

This 30-year-old man involved in a motor vehicle accident was found unconscious on the road after being ejected from his vehicle. He was intubated in the field, where his Glasgow Coma Scale score was 7. Initial cervical radiography demonstrated significant swelling of the prevertebral soft tissue. Sagittal CT reconstruction revealed widening of the atlantoaxial joint. In the coronal plane, we observed asymmetry of the C-1 lateral masses in relation to the right or left condyles (Fig. 2 upper left) and a teardrop fracture at the medial aspect of the occipital condyle. Magnetic resonance imaging with short tau inversion-recovery sequences demonstrated hyperintensity involving the atlantoaxial and occipitoatlantal joints (Fig. 2 upper center). On T2-weighted MR images, the alar ligament appeared to be detached from the ipsilateral condyle. The patient was placed in a halo vest. Additional head CT scanning revealed intraventricular blood and traumatic subarachnoid hemorrhage that required placement of an external ventricular drain to monitor intracranial pressure.

Use of dual transarticular screws to fixate simultaneous occipitoatlantal and atlantoaxial dislocations

Case report

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O ccipitoatlantal dislocation and atlantoaxial vertical distraction are caused by similar mechanisms, and few individuals survive these injuries. It is hypothesized that the injurious vertical force manifests as a traumatic lesion at different levels of the same ligamentous complex. The authors report the cases of two patients who presented with this combined lesion, describe surgical alternatives for stabilization, and introduce a new technique that combines the use of transarticular screws in a “dual” construct, without involving the unaffected spine.

KEY WORDS • atlantoaxial dislocation • distraction injury • craniovertebral junction • occipitoatlantal dislocation

Abbreviations used in this paper: AAD = atlantoaxial dislocation; CT = computerized tomography; CVJ = craniovertebral junction; OAD = occipitoatlantal dislocation; VA = vertebral artery.
Once the patient was clinically stable, he underwent occipitocervical fusion (Fig. 2 upper right). The occiput and atlas were fixated with transarticular screws that traversed from the C-1 lateral mass to the occipital condyle, in a divergent and rostral trajectory.\textsuperscript{7,9,10} As described by Magler, C1–2 transarticular screws were placed to treat the AAD injury.\textsuperscript{2} Frameless stereotaxy and intraoperative CT scanning (Iso-C; Siemens Medical Solutions, Erlangen, Germany) were used to assist in the placement of the transarticular screws. After four screws were inserted, a new intraoperative CT scan was obtained to verify the trajectory of the screws. Tricortical autograft was harvested from the iliac crest. An H-shaped graft was carved and compressed between the suboccipital surface and C-2. Atlantal, axial, and occipital surfaces were decorticated using a pneumatic drill to facilitate fusion. Using a braided cable (Songer; Sofamor Danek, Memphis, TN) the bone graft was secured to the occipital bone through a tunnel drilled at the base of the occipital crest and running along the C-2 spinous process caudally. A second sublaminar wire was placed under the posterior arch of C-1 along the graft. The position of the screws and graft was verified on postoperative imaging (Fig. 2 lower left and right).

The patient’s neurological status improved, and ultimately he was weaned from intracranial pressure monitoring and the endotracheal tube was extubated. He recovered from his head and spine injuries and was transferred to a rehabilitation facility outside the US where he is now ambulatory, according to his family. No further follow-up information is available.

Discussion

We have described two cases of CVJ trauma in which an obvious separation occurred between the atlas and occipital condyle and simultaneously between the atlas and axis, as reported by Traynelis and colleagues.\textsuperscript{13} A sound knowledge of the ligamentous anatomy of the CVJ is needed to understand both injuries (Fig. 3). The most important structures contributing to the stability of the CVJ are the tectorial membrane, and the apical, alar, and cruciate ligaments.\textsuperscript{3} This complex ligamentous array keeps the atlas sandwiched between the occiput and axis. The cruciate ligament has two interwoven bands, one vertical and one horizontal. The horizontal band (transverse ligament) is inserted bilaterally in the medial aspects of the C-1 lateral masses and serves as a restraint to prevent posterior displacement of the odontoid process into the spinal canal. The vertical portion is inserted rostrally on the most caudal aspect of the clivus and caudally on the dorsal aspect of the C-2 vertebral body.

We hypothesize that during pure axial distraction of the CVJ, different types of injury will manifest depending on where the vertical portion of the cruciate ligament is disrupted (Fig. 4). In both OAD or AAD, the transverse ligament is likely intact because in patients suffering these injuries, evidence of anteroposterior subluxation is seldom shown (Fig. 5). If all vertically compressive ligaments (apical, alar, and tectorial membrane) and articular capsules are sectioned, and the vertical portion of the cruciate ligament inferior to the transverse ligament is disrupted (Fig. 4B). In both OAD or AAD, the transverse ligament is ruptured above the transverse ligament, the result should be OAD (Fig. 4B). In the laboratory, ligaments in cadaveric specimens were intentionally cut in this pattern to represent OAD.\textsuperscript{11} If the articular capsules between C-1 and C-2 and the vertical segment of the cruciate ligament inferior to the transverse ligament fail, distraction should occur at C1–2 (AAD) rather than the occipitoaxial junction (Fig. 4C).\textsuperscript{8}

Our theory has not been validated and is not necessarily the only explanation for the differences in injury type.
Fig. 2. Case 2. Upper Left: Coronal CT reconstruction revealing the asymmetry of the C-1 lateral mass with respect to C-2 as well as between the occipital condyles and C-2. Upper Center: Sagittal short tau inversion-recovery magnetic resonance image revealing high signal intensity at the occipital condyle–atlas joint and at the C1–2 joint. Upper Right: Intraoperative photograph demonstrating the four transarticular screws and bone graft secured to both C-1 and C-2 with a braided cable. Lower Left: Postoperative lateral radiograph revealing the placement of the transarticular occipitoatlantal screw and atlantoaxial screw fixation construct. The posterior bone graft is secured with wires. Lower Right: Computed tomography reconstruction revealing the four transarticular screws.

Fig. 3. Illustration of the ligamentous anatomy of the CVJ. Used with permission from the Barrow Neurological Institute.
Another possibility is that the different injuries may occur because the ligaments at the two joints respond differently to different injurious loading rates. If so, OAD may be more prevalent at a high loading rate, whereas AAD might be more prevalent at a low loading rate or vice versa. A third possibility is that one injury occurs when the distraction vector is purely axial, whereas the other injury occurs when secondary forces are present. For example, an angled loading vector might somehow allow shielding of the ligamentous forces across one joint but not the other because of interactions of osseous articulations. In our laboratory, experiments are currently being performed to attempt to validate our injury model.

We have treated patients with isolated OAD, and isolated AAD. The cases described in the present report involved a combined OAD and AAD injury. The injury in Case 1 was more severe than that in Case 2. We hypothesize that if the cruciate ligament is disrupted both above and below the transverse ligament and the articular capsules are injured, then a combined occipitoatlantal and atlantoaxial injury (OAD and AAD) will occur (Fig. 4D).

In patients who survive OAD, AAD, or combined dislocation, rigid internal fixation is the treatment of choice. Wires, plates, and screws have been used in various combinations to achieve occipitoatlantal, atlantoaxial, or occipitoatlantoaxial fixation. Wires and screws are used with a metal frame affixed to the subaxial spine by sublaminar wires, and screws are used to anchor the frame to the suboccipital surface. The applications of these techniques depend on the variable thickness of the occipital bone, the potential for penetrating the dura mater with the screws, eventual epidural bleeding, and the passage of wires beneath the laminae, which can provoke or worsen spinal compression. The instrumentation also often needs to be extended to the subaxial spine.

If an isolated AAD occurs without associated injuries (no OAD or fractures), C1–2 fusion alone is indicated; this involves either C1–2 transarticular screws or C-1 lateral mass screws and C-2 pedicle screws interconnected with rods. In the case of an isolated OAD and no other superimposed injuries, the best treatment, physiopathologically, would be transarticular screw fixation of the

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**Fig. 4.** Simplified illustrations of the CVJ in the coronal plane demonstrating the normal anatomy and the theoretical difference between OAD, AAD, and occipitoatlantoaxial dislocations. A: In the normal condition the cruciate ligament maintains close apposition of the occiput–C1 and C1–2 junctions. B: If the vertical cruciate is sectioned superior to the transverse portion of the cruciate ligament, OAD occurs. C: If the vertical cruciate is sectioned inferior to the transverse portion of the cruciate ligament, AAD occurs. D: If both the horizontal and vertical portions of the cruciate ligament are sectioned, the resulting injury is a combination of OAD and AAD. Adapted from Fig. 6 in Gonzalez LF, Fiorella D, Crawford NR, et al: Vertical atlantoaxial distraction injuries: radiological criteria and clinical implications. *J Neurosurg (Spine)* 3:273–280, 2004.

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**Fig. 5.** Axial CT scan obtained at the atlantoaxial junction in a patient with vertical C1–2 subluxation, revealing normal anteroposterior alignment between the C-1 anterior arch and the C-2 body.
compromised occipitocervical joint.\textsuperscript{5-8,10} Because of the
continuity of the craniovertebral ligaments that initiate from
the occiput, pass C-1, and terminate at C-2, pure isolated
OAD and AAD would be theoretically impossible. It is
therefore important for the surgeon to scrutinize each case
so as not to miss the presence of concomitant OAD during
AAD and AAD during OAD. There are, however, docu-
mented cases of OAD in which the remaining ligaments
across the C1–2 junction are adequate for clinical stabili-
ty,\textsuperscript{6} and there are also cases of AAD in which the remain-
ing ligaments across the occipitocervical junction are ade-
quate for clinical stability.\textsuperscript{8}

When introduced from the C-1 lateral mass under the
sulcus arteriosus with a shallow trajectory that allows
piercing of the occipital condyle, cannulated screws may
potentially penetrate the hypoglossal canal. The use of
intraoperative image guidance and preoperative evalua-
tion of the CT scans can help prevent this. Extensive flex-
ibility testing has been performed\textsuperscript{7} to compare the transar-
ticular screws with a standard fixation procedure (a loop
attached to the suboccipital surface with screws and at-
tached caudally to the subaxial spine with transarticular
C1–2 screws). Transarticular screw fixation significantly
reduces motion compared with the normal range as well
as after severe instability during flexion–extension, lateral
bending, and axial rotation.\textsuperscript{7} This technique preserves
the normal range of motion during axial rotation at C1–2.\textsuperscript{7,9}

If C-1 is “loose” between the occipital condyles and
C-2 (combined OAD and AAD), occipitocervical fixation
is required. One should consider an alternative technique,
such as placing bilateral transarticular screws from the
occipital condyle to C-1\textsuperscript{16} in combination with bilateral
C1–2 transarticular fixation (Magerl technique).\textsuperscript{5,8} Our
Case 2 represents the first description of this construct.

\textbf{Fig. 6.} Photograph of a cadaveric specimen during dissection, revealing the anatomical feasibility of placing the con-
struct with dual transarticular screws. C0 = occiput; V3 = third segment of the VA.
Dual screw fixation after occipitoatlantal trauma

(Fig. 2). The construct pins the affected joints and apposes the fragments as soon as the screw pierces the joint because the screw creates a lag effect that provides immediate rigid fixation. Compromise of segments unaffected by the injury is thereby eliminated. The trajectory of these screws, which are distant from each other, is almost parallel. Anatomical feasibility of this fixation method was demonstrated (Fig. 6) and adequate bone purchase was therefore available for each screw as corroborated by preoperative CT scanning. Frameless stereotaxy and intraoperative CT scanning are helpful surgical adjuncts for placing transarticular screws.

Other techniques could be used for occipitoatlantal fixation without involving segments below C-2, such as the construct created by an occipital loop connected to C1–2 transarticular screws.7 We prefer to use transarticular occipital condyle–C1 screw fixation together with transarticular C1–2 screw fixation because of the theoretical advantages conferred by these combined constructs: they have a lower profile and the lag effect compresses the joints together. In this technique, the thickness of the occipital bone is irrelevant. Furthermore, there is no risk of creating potential cerebellar or epidural hematomas. Compression is thought to improve fusion rates. Although transarticular screws are known to be weakest during flexion and extension, the addition of wired-fixed posterior graft should overcome this weakness by serving as a buttress and tension band against sagittal-plane motion.

Conclusions

Based on these two cases, we hypothesize that vertical subluxation injuries at the CVJ (OAD, AAD, or both) share the same distractive mechanism, which tears the thick ligaments and causes severe instability. Fractures are seldom present, but the consequences are often lethal. The rostrocaudal location of the lesions is the critical factor in differentiating OAD from AAD. In such injuries, the unstable level should be stabilized without compromising unaffected adjacent levels. In one of our patients we implanted a dual construct of transarticular screws inserted along an almost parallel trajectory. This type of construct should be considered as an alternative to existing fixation systems.

References


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