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# Fractures of the C1 and C2 Vertebrae

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ABSTRACT

Upper cervical fractures of the axis and atlas (C1 and C2, respectively) typically occur in children and in the elderly population. The anatomic characteristics of the craniocervical junction allows for unique fracture patterns. Jefferson fractures of the atlas are the classic fracture presentation of the C1 vertebrae. Odontoid fractures and traumatic spondylolisthesis of the axis are the most commonly reported fractures of the C2 vertebrae. This chapter will review the anatomy, injury mechanisms, and fracture types seen in the C1 and C2 vertebrae. In addition, several nonoperative and operative treatment options, supported by the literature, will be discussed.



Fractures of the axis and atlas are most often encountered in children and in those aged >60. The osseoligamentous complex that protects the upper cervical spine is anatomically and functionally distinct from those of the subaxial cervical spine. This helps explain the specific modes of injury encountered with fractures in these vertebrae.

Injuries to the C1-C2 complex account for up to 70% of all cervical spine trauma in patients older than 60 years, with 57% of these injuries occurring in the odontoid.[1] These are typically low-energy trauma events without neurologic injury. In the young adult population, most patients are males with high-energy mechanisms of injury. Most cervical trauma occurs in the subaxial spine; however, when the upper cervical spine is involved, it can be associated with neurologic injury with high morbidity and mortality of the patient.

Improvements in emergency and trauma care in stabilizing trauma victims, and in imaging modalities that can better detect these injuries have greatly decreased mortality and enhanced overall outcome. When applicable, advances in internal fixation techniques have greatly improved overall functional outcomes allowing earlier mobilization and rehabilitation.

## 1. Anatomy

Upwards of 50% of motion occurs in the upper cervical spine, consisting of the occiput, atlas, and axis.[2] The atlas, or C1, is the first of 7 cervical vertebrae and is responsible for transmitting loads from the skull to the cervical spine. It is unique in that its vertebral body is incorporated into the dens, which is part of the axis, or C2. Instead of a vertebral body, the atlas has 2 large lateral masses connected by an anterior and posterior arch (Fig. 1). These lateral masses form articulations with the occipital condyles above and the superior articular facets of the axis below. The oblique position of the occiput-C1 joint in the coronal plane results in compressive loads from the skull that radiate outward into the C1 ring. These articulations allow for 50% of the total cervical flexion and extension at the occiput-C1 joint and 50% of the total cervical rotation at the C1-C2 joint.[3] The anterior arch contains a tubercle for the insertion of the anterior longitudinal ligament (ALL) and longus colli muscles. The ALL also attaches to the anterior margin of the body of C2. There is no true spinous process as the posterior arch has only a small tubercle that allows for the attachment of the ligamentum nuchae. Steele described the spinal canal of the atlas as consisting of one-third odontoid process,

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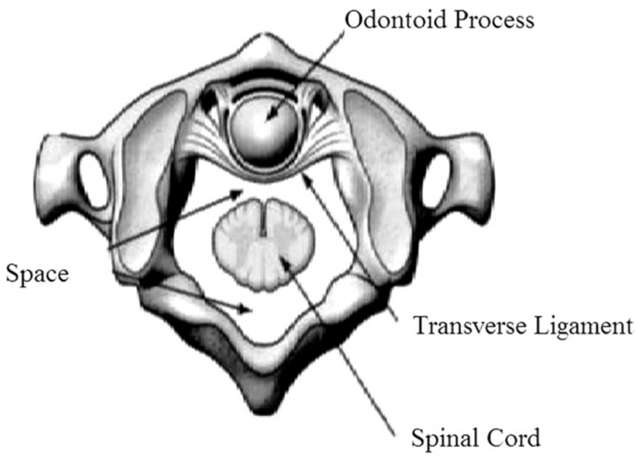


**Figure 1 – Axial view of the atlas vertebrae. Steele's "rule of thirds of structures" refers to one-third odontoid, one-third spinal canal, and one-third free space.**

one-third spinal canal, and one-third free space. This has come to be known as "Steele's rule of thirds."[4] Clinically, the space present in the canal allows a relatively large amount of anterior translation without adverse neurologic consequences.

The vertebral artery enters C1 through the foramen transversarium, then crosses along the posterior arch of the atlas thinning it at that location. The vertebral artery may be injured in C1 and C2 fractures (Fig. 2). One must be careful exposing the posterior ring of C1 surgically to avoid injury to the vertebral artery. The artery is typically located 1.5 cm lateral to midline in adults and 1 cm lateral to midline in children.

As there are no disks between the occiput and C1 and between C1 and C2, the upper cervical spine relies heavily on its ligamentous structures for stability. The primary stabilizers of the C1-C2 articulation are the cruciate ligament, the transverse atlantal ligament, the apical ligament, and the alar ligaments (Fig. 3). The cruciate ligament attaches to the basion and to the body of C2 and is the main ligamentous stabilizer of the occiput-C1-C2 complex. The transverse ligament extends transversely from one condyle of the atlas to the other and apposes the posterior dens and is the most crucial ligamentous stabilizer of the atlantoaxial complex. It is primarily responsible in preventing anterior subluxation or dislocation of C1 on C2. Secondary stabilizers of the atlantoaxial complex are the alar and apical ligaments. The alar ligaments are paired structures that connect the superolateral odontoid process to the anteromedial surface of the occipital condyles. The alar ligaments limit axial rotation to the opposite side providing stability to the atlas.[5] The apical ligaments connect the tip of the dens to the anterior foramen magnum.

Muscular attachments also play a stabilizing role in the upper cervical spine. As previously discussed, the superior oblique portion of the longus colli attaches to the anterior and inferior arch of C1. The rectus capitis lateralis and medialis pass from the transverse process of C1 to the lateral and anterior portions of the foramen magnum. The rectus capitis posterior passes from the posterior arch of C1 to the occiput. The superior oblique muscle laterally traverses from the lateral aspect of the ring of the atlas to the posterior surface of the skull, and the inferior oblique muscles pass from C2 to the lateral aspect of the C1 ring.

Anatomically, the axis (C2 vertebrae) is distinct from the atlas and the subaxial vertebrae. Injuries to the anterior portion of C2 are included in upper cervical injuries, and those in the C2-C3 facet joints have features similar to subaxial cervical spine injuries. The most unique anatomic characteristic of the axis is the presence of the dens or odontoid process. The dens results from fusion of the axis with the remnant of the vertebral body of the atlas. Its main function is to transition between the upper and lower portions of the cervical spine, which is facilitated by its articulating facets. The superior facets are anterior and lateral, and the inferior facets are posterior. The C2 neural arch is divided into the pedicle, the pars interarticularis, and the lamina. The vertebral artery passes through the foramen transversarium in the superolateral lateral mass of C2, which is adjacent to the pars. Although often interchanged, the pedicle and pars of C2 are distinct structures. The pedicle forms a posterolateral extension of the vertebral body connecting the body to the lateral mass. The pars is a narrow segment of bone that bridges the superior facet with the inferior facet. Because of the spatial separation of the facets, the pars experiences a significant bending force, making it susceptible to injury. The C1-C2 articulation is highly congruent, and its joint capsules may also be secondary stabilizers of the craniocervical junction. The odontoid gets its blood supply from the anterior and posterior ascending arteries as well as the cleft perforating artery. Through their anastomoses, they form an extensive vascular network surrounding the odontoid but create a watershed area at its base. A higher rate of nonunions noted with odontoid base fractures is because of this watershed area.[6]

## 2. Atlas Fractures

Fractures of the atlas were initially described in 1822 by Sir Astley Cooper.[7] Almost 100 years later, Dr. Geoffrey Jefferson

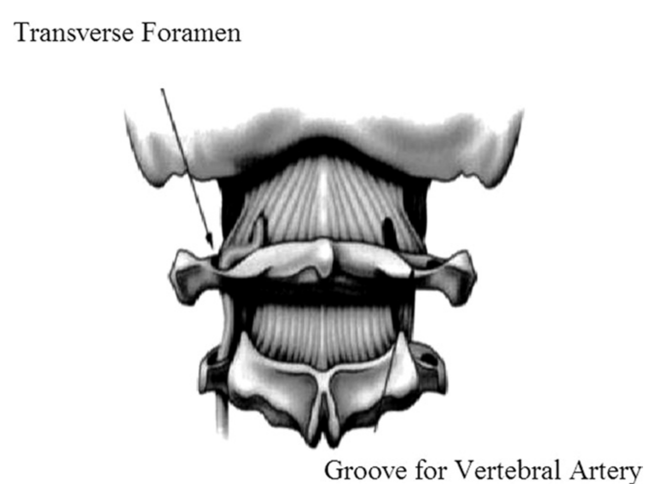


**Figure 2 – Posterior view of the craniocervical junction demonstrating the course of the vertebral artery.**