Anatomy

2

Andrés Combalia

A thorough knowledge of the anatomy of the cervical spine is essential for the performance of surgical procedures. Recent qualitative and quantitative studies using cadaver dissection, computed tomography, and magnetic resonance imaging have continued to add to our knowledge of the dimension of and the clinically relevant relations between cervical spine structures. This chapter discusses the normal anatomy of the second cervical vertebra and its relations.

2.1 Osseous Components of Craniocervical Junction

The first (atlas) and second (axis) cervical vertebrae are considered atypical compared with those of the lower cervical spine. Atlas lacks a body and a spinous process. It is a ring-like structure consisting of two lateral masses connected by a short anterior arch and a longer posterior arch. It is the widest cervical vertebra, with its anterior arch approximately half as long as its posterior arch (Fig. 2.1). Located in the midline of the anterior arch is the anterior tubercle for the attachment of the anterior longitudinal ligament and the longus colli muscles. The posterior arch corresponds to the lamina of the other vertebrae. On its upper surface is a wide groove for the vertebral artery and the first cervical nerve. In 1–15 % of the population, a bony arch may form, thereby converting this groove into the arcuate foramen, through which passes the same structures [1–3]. On the posterior arch is a posterior tubercle for attachment of the ligamentum nuchae. The lower surface is notched, which contributes to the formation of the C2 intervertebral foramen. The lateral masses of the atlas give rise to a superior and inferior articular facet. The transverse process is larger than that of other cervical vertebrae and is composed solely of a posterior tubercle that, with the costotransverse bar that attaches to the lateral mass, contains the foramen transversarium. An important anatomic feature of the atlas is the inward projection of a prominent tubercle of bone on each side cranial and medially to the lateral masses. These structures give rise to the transverse ligament that keeps the dens confined to the anterior third of the atlantal ring. This relation allows free rotation of the atlas on the dens and axis and provides, together with the other ligaments for a stable configuration in flexion, extension and lateral bending [4].

The axis is also known as the epitropheus. It is characterized by a dens or odontoid process that projects upward from the vertebral body to articulate with the posterior aspect of the anterior arch of the atlas (Fig. 2.2). The dimensions

A. Combalia (✉)
Orthopaedic Surgery and Traumatology, Hospital Clínic, University of Barcelona and Department Human Anatomy, Faculty of Medicine, University of Barcelona, Villarroel 170, Barcelona, 08036, Spain
e-mail: combalia@clinic.ub.es

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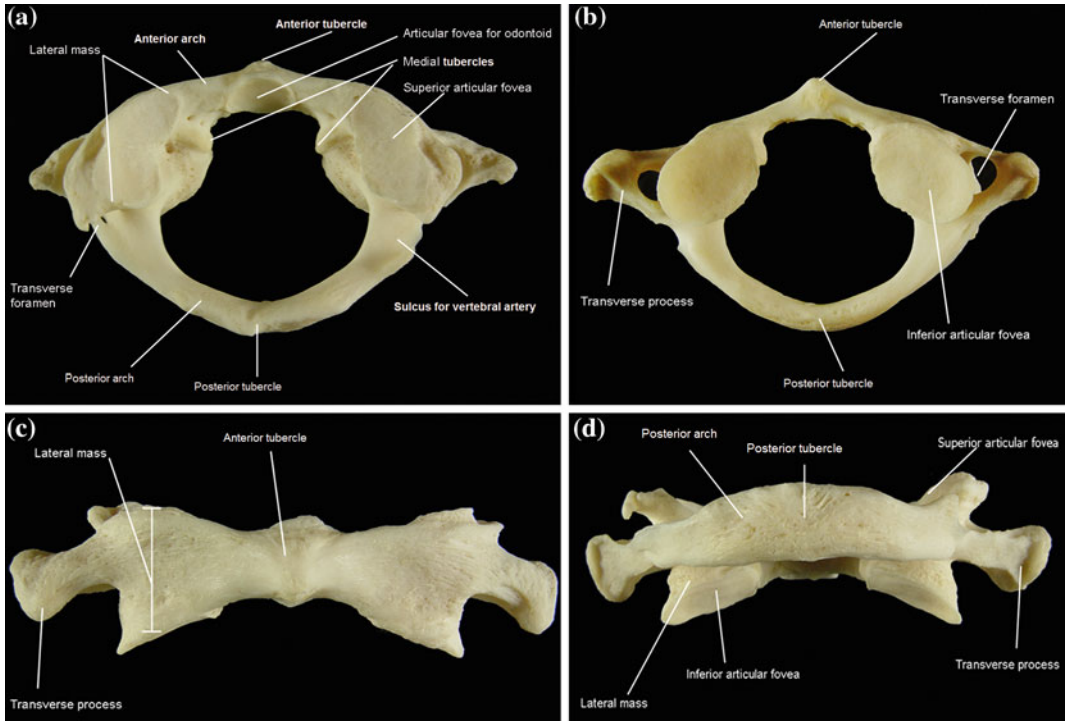


Fig. 2.1 The atlas: **a** cranial view, **b** caudal view, **c** anterior view, **d** posterior view

of the dens are highly variable: Its mean height is 37.8 mm, its external transverse diameter is 9.3 mm, internal transverse diameter is 4.5 mm, mean anteroposterior external diameter is 10.5 mm, and internal diameter is 6.2 mm [5]. Lateral to the dens, the body has a facet for the lower surface of atlas' lateral mass, which is large, slightly convex, and faces upward and outward. It is not a true superior articular process because the articular surface arises directly from the body and pedicle lateral to the dens. The zone between the lamina and the lateral mass is not well defined and comprises a large pedicle/isthmus that is 10 mm long and 8 mm wide [6]. It projects superiorly and medially in an anterior direction. The lower surface of the lateral mass has a forward-facing facet that articulates with the superior articular process of C3. Axis' pedicle/isthmus plays an important role regarding screw purchase for spinal fixation. The location of axis' pedicle remains a subject of controversy. Although some authors have reported that the pedicle connects the vertebral body to the superior articular process [7, 8], others have defined the pedicle as the portion beneath and posterior to the superior facet [9–12]. There is a confusion regarding the terminology of these structures. A pedicle is a portion of the vertebrae connecting the ventral and dorsal elements. Although this is valid for all subaxial vertebrae, the axis' pedicles are anatomically unique. Although the superior articular process is a posterior element of the vertebra (i.e., posterior to vertebral body in the axial plane) in all subaxial vertebrae, an inspection of the axis reveals that its superior articular process is not anatomically posterior to the vertebral body. Naderi et al. [13] studied 160 axis' pedicles (80 dry vertebrae). The isthmus (pars interarticularis) and the pedicle are distinct structures. The axis does not have an isolated pedicle, which can be observed in the subaxial vertebrae. There exists a complex containing the pedicle inferiorly and the isthmus superiorly. Whereas the isthmus connects the superior and inferior articular processes, the true pedicle

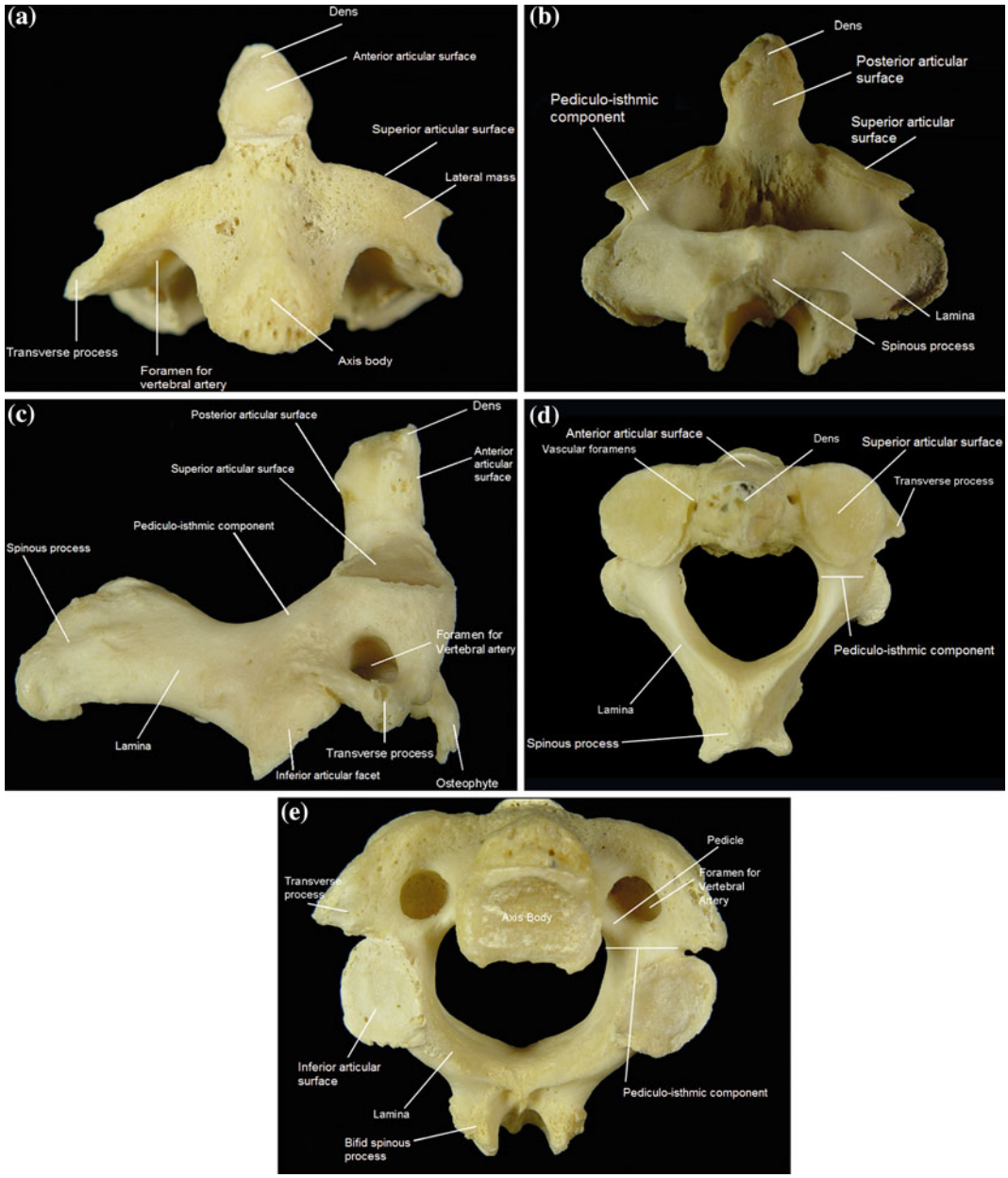


Fig. 2.2 The axis: **a** anterior view, **b** posterior view, **c** lateral view, **d** cranial view, and **e** caudal view

connects the lateral mass and inferior articular process to the vertebral body.

The pedicle of the axis is covered by the facet joint and integrated with the isthmus. Therefore, for Naderi et al. [13], it is more appropriate to term these two components as the pediculoisthmic components (PIC) due to the fact that although both are distinct structures they are closely integrated. The axial PIC is posterolateral to the vertebral body, medial to the transverse foramen, originates posterolaterally from the lateral mass and inferior articular process junction, and ends anteromedially at the vertebral body–odontoid process junction. It is grooved

laterally by the transverse foramen. The axis' isthmus covers the pedicle. The heights of the right and the left PICs in the Naderi et al. study were 10.3 ± 1.6 and 9.9 ± 1.5 mm, respectively. The posterior part of the superior aspect of the PIC is wider than the anterior portion. The widths of the posterosuperior aspect of the PIC were 11.1 ± 2 and 11 ± 1.7 mm on the right and left sides, whereas the widths of the anterosuperior aspect of the PIC were 7.9 ± 1.7 and 8.5 ± 1.6 mm, respectively. The inferior widths of this component were 6.0 ± 1.5 and 5.5 ± 1.3 mm on the right and left sides, respectively. The lengths of the component were 28.8 ± 2.9 mm on the right and 28.8 ± 3.4 mm on the left side [13]. The PIC exhibits a lateral-to-medial angle and an inferior-to-superior angle. Its axial angles were 28.4° ± 2.5° and 28.6° ± 2.2° on the right and left sides, respectively; its sagittal angles were 18.8° ± 2.1° and 18.8° ± 1.7°, respectively. In summary, axis' pedicle can be seen in the inferior aspect of the vertebra, and it connects posterior vertebral elements (i.e., the lateral mass and inferior articular process) to the axial body. The isthmus or pars interarticularis drapes the pedicle.

The laminae of the axis are thick, and the spinous process is large and bifid. The transverse process ends in a single tubercle and contains a foramen transversarium. Cassinelli et al. [14] measured the laminar thickness (LT) in the narrowest laminar section in American populations and reported that more than 70.6 % of the specimens they studied had a LT > 5 mm. Mean laminar thickness was 5.77 ± 1.31 mm; 92.6 % had a thickness ≥4.0 mm. The spinolaminar angle was 48.59° ± 5.42°. Ma et al. [15] evaluated axis' lamina in Asian population. A total of 83.3 % specimens had bilateral laminar thicknesses ≥4.0 mm and a spinous process height ≥9.0 mm. Wright in 2004 [16] described a new technique for fixation involving bilateral, crossing laminar screws. More than 99 % of specimens in the Cassinelli study had an estimated screw length of at least 20 mm. Gender had a significant effect on all of the measurements studied. It is not likely, however, that all of these differences are clinically significant. White males had the thickest laminae, while white females had the thinnest. Laminar thickness was 0.46 mm (8.3 %) less in females than in males. There was no statistical effect of patient race, height, or weight on any of the measurements [14]. Several other studies examining the LT came to similar conclusions: Most of the specimens they examined had an LT larger than the diameter of the commonly used cervical screw (3.5 mm). Although the minimum laminar thickness required to allow for safe placement of a screw was not described, there is a common idea that a thickness >5 mm with a precise screw trajectory may be acceptable [17, 18].

The spinal nerve exits posterior to the superior articular surface of the axis rather than anterior to the articular complex, as spinal nerves do at other levels. Large pediculoisthmic structures and a deeper spinal canal are two factors that allow increased mobility at the axis without cord encroachment. The density of the trabecular bone of the axis varies: It is very dense near the center of the tip of the dens and lateral masses beneath the superior articular surface, and hypodense in the area of the trabecular bone immediately beneath the dens. An area of cortical thickening on the anterior surface of the axis, known as the promontory of the axis, underlies the insertion of the anterior longitudinal ligament [19, 20].

The occipital condyles have also been thoroughly described. The occipital condyles are the paired lateral prominences of the occipital bone that form the foramen magnum together with the basioccipital segment anteriorly and the supraoccipital or squamosal segment posteriorly. The occipital condyles are commonly oval or bean shaped and slope inferiorly from lateral to medial in the coronal plane. The condyles make an angle of 25°–28° with the midsagittal plane. The occipitoatlantal articulations are cup-shaped paired joints between the convex occipital condyles and the concave superior atlantal facets. The condylar part of the occipital bone is perforated by the hypoglossal or anterior condyloid canal/foramen. Two structures travel through this canal; the hypoglossal nerve (cranial nerve

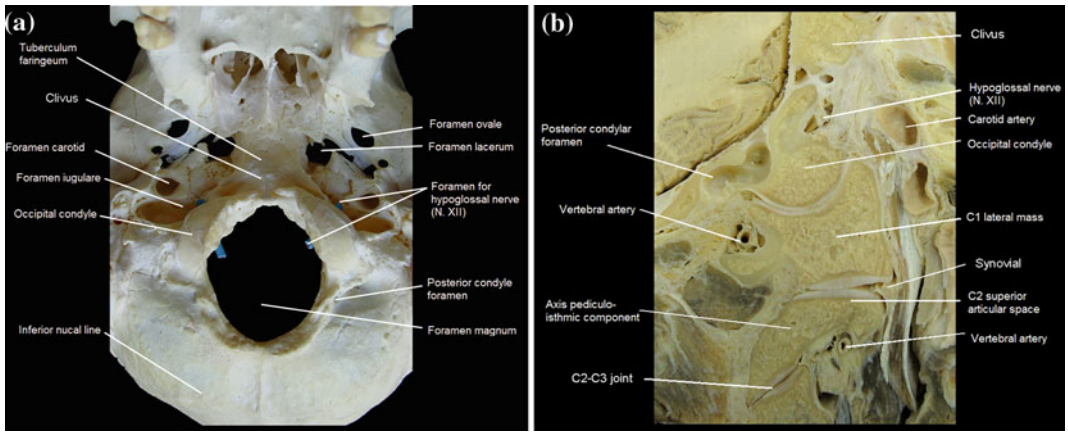


Fig. 2.3 Occipital condyles: **a** caudal view of the cranium, **b** paramedian section passing through the right occipito–atlas–axis joints

XII) exits the skull, while a meningeal branch of the ascending pharyngeal artery enters it (Fig. 2.3). Behind the occipital condyles, there is an indentation known as the condyloid fossa, which is frequently perforated by the posterior condylar foramen. And emissary vein runs through the posterior condylar canal from the sigmoid sinus. Sometimes there is also an artery which anastomoses with the posterior meningeal artery. Cranial nerves IX to XI, the inferior petrosal sinus, the internal jugular vein, and the posterior meningeal artery travel lateral to the occipital condyles in the jugular foramen.

The spinal canal is formed by sequential vertebral foramina and is triangular with rounded edges. It has a greater lateral than AP width and is more spacious in the upper cervical spine, with sagittal diameters averaging 23 mm at the atlas and 20 mm at the axis. In comparison, the average diameter from C3 through C6 ranges between 17 and 18 mm and decreases to 15 mm at C7 [21]. Thus, the cross-sectional area of the cervical spinal canal is greatest at the axis and smallest at C7.

2.2 Articulations, Biomechanics, and Ligaments

The craniovertebral junction is composed of 2 major joints: the atlantooccipital and the atlantoaxial joints. These joints are responsible for the majority of the movement of the cervical spine and operate on different biomechanical principles. The mechanical properties of the atlantooccipital joint are primarily determined by bony structures, whereas the mechanical properties of the atlantoaxial joint are mainly determined by ligamentous structures [22]. The prominent movements at the atlantooccipital joint are flexion and extension.

The various movements at this joint occur because the condyles glide in the sockets of the atlas [23]. Panjabi et al. [24] found the atlantooccipital joint to be responsible for 27.1° of flexion and 24.9° of extension. They also noted that about 8° of axial rotation can take place at this joint, as well as minimal lateral and anteroposterior translation. Steinmetz et al. [22] reported similar values, with a mean movement of 23°–24.5° of flexion/extension, whereas axial rotation was limited to 2.4°–7.2°. They reported that flexion was limited by impingement of the odontoid process on the foramen magnum, and extension was restricted by the tectorial membrane. Lateral flexion is strongly inhibited at the atlantooccipital joint by the contralateral alar ligament [25]. The primary movement at the atlantoaxial joint is axial rotation. Steinmetz et al. [22] reported that the mean axial rotational movement was between 23.3° and 38.9°. Menezes and Traynelis [23] noted that axial

rotation beyond 30°–35° can cause vertebral artery occlusion. Flexion and extension at the atlantoaxial joint range from 10.1° to 22.4° and are limited by the transverse ligament and tectorial membrane, respectively. Lateral bending is restricted to 6.7° by the contralateral alar ligament. Although these two joints function differently, they must act in unison to ensure optimal stability and mobility at the craniovertebral junction.

The atlantooccipital complex is composed of two membranous attachments between the atlas and the occiput and the two synovial atlantooccipital joints laterally. The atlantooccipital joints are formed between the superior articular facet of the atlas and the occipital condyle. These joints contain a synovial membrane and are surrounded by a capsular ligament. Also contributing to the complex are the anterior and posterior atlantooccipital membranes, connecting the anterior and posterior arch of the atlas with the corresponding margin of the foramen magnum. The anterior atlantooccipital membrane blends on its lateral edges with the capsular ligaments of the synovial joints and inferiorly with the anterior longitudinal ligament. The posterior atlantooccipital membrane blends laterally with the capsular ligaments of the synovial joints and is pierced on each side just above the posterior arch of the atlas by the vertebral artery and the first cervical nerve (Fig. 2.4) [1].

The atlantoaxial complex is composed of three synovial joints, one median and two lateral. The lateral atlantoaxial joints consist of an encapsulated synovial joint between the inferior articular facet of the atlas and the superior articular surface of C2 (Fig. 2.3b). The capsule is reinforced posteriorly by an accessory ligament that extends from the posterior aspect of the axis superiorly and laterally to the lateral mass of the atlas [25]. This accessory atlantoaxial ligament runs at the lateral edge of the tectorial membrane and is sometimes called the "accessory part of the tectorial membrane". In a thorough description by Tsakotos et al. [26], the attachment of the tectorial membrane and the accessory atlantoaxial ligament was 0.6–1.1 cm (mean 0.9 cm) inferior to the internal opening of the anterior condylar canal (hypoglossal canal) and posterior to the cephalic attachment of the alar ligament. The maximal tension of the accessory atlantoaxial ligament was observed during rotation of the head at 5°–8°. The ligament remains lax with cervical extension and

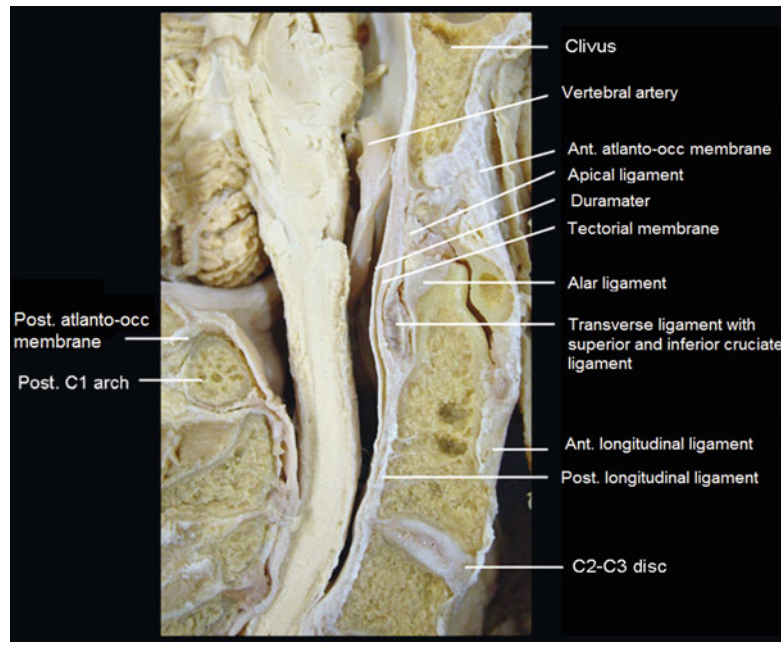


Fig. 2.4 Median section at craniovertebral junction showing atlantooccipital and atlantoaxial ligaments and anatomic structures

shows no tension during cervical flexion. Its function seems to assist the alar ligament in inhibiting excessive rotation of the head, since its maximal tautness ranges from about 5° to 10°. The median atlantoaxial joint forms between the anterior arch and transverse ligament of the atlas and the dens. It is a pivot joint with synovial membrane and capsular ligaments anteriorly and posteriorly to the dens. The cruciate or cruciform ligament is composed of the transverse ligament of the atlas and the superior and inferior ligamentous extensions that connect it to the anterior edges of the foramen magnum and posterior aspect of axis' body, respectively. The transverse ligament attaches laterally to a small tubercle located on the medial aspect of the lateral mass of C1, where it blends with the lateral mass (Figs. 2.4, 2.5, 2.6). The length of the transverse ligament averages 21.9 mm. It is the largest, strongest, and thickest craniocervical ligament (mean height/thickness 6–7 mm) [25]. The transverse ligament maintains stability at the atlantoaxial joint by locking the odontoid process anteriorly against the posterior aspect of the anterior arch of the axis, and it divides the ring of the atlas into two compartments: the anterior compartment houses the odontoid process, and the posterior compartment contains primarily the spinal cord and spinal accessory nerves. The ligament also has a smooth fibrocartilaginous surface to allow the odontoid process to glide against it [23]. The tectorial membrane, epidural fat, and dura mater are located dorsal to the transverse ligament. The biomechanical data reported by Fielding et al. [27] demonstrated that the transverse ligament is the primary defense against anterior subluxation of the atlas on the axis and that it is relatively inelastic, only allowing C1 to subluxate approximately 3–5 mm before rupturing.

The axis has three other connections to the occipital bone, the apical ligament, and the alar ligaments. The apical ligament , also known as suspensory ligament, extends from the tip of the dens to the anterior edge of the foramen magnum. Panjabi et al. [24] reported the length of the apical ligament to be 23.5 mm and a 20° anterior tilt, describing the ligament as broad and fan shaped at its insertion onto the basion. They also reported the ligament as tightly adherent to the overlying tectorial membrane. The ligament runs in the triangular area between the left and right alar ligaments known as the supraodontoid space (apical cave) [28] and

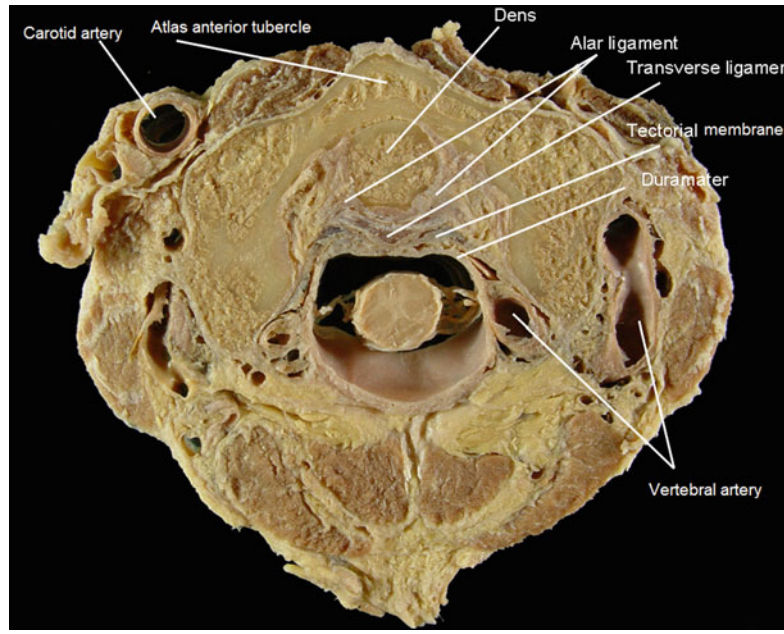


Fig. 2.5 Transversal section at atlanto–odontoid joint

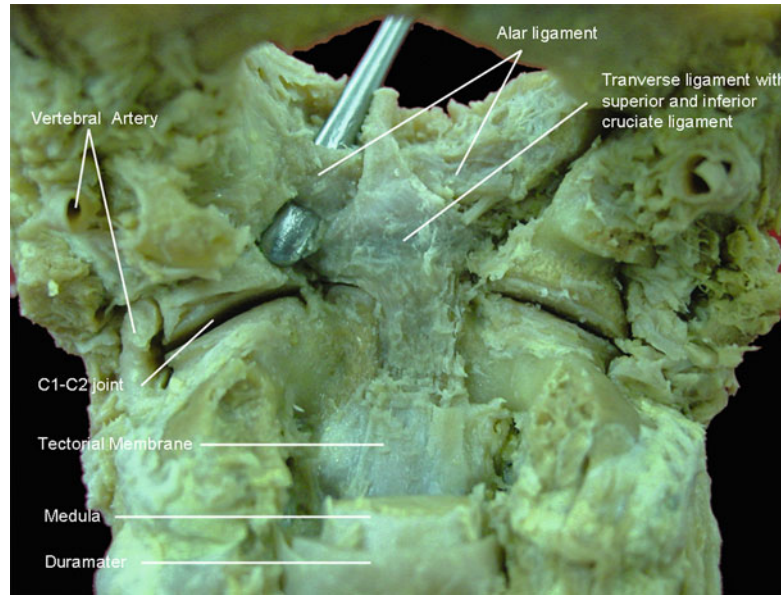


Fig. 2.6 Posterior view of the ligaments and joints at craniovertebral

travels just posterior to the alar ligaments and just anterior to the superior portion of the cruciform ligament. In 2000, Tubbs et al. [29] conducted a cadaveric study focusing on the apical ligament and found the mean length and width to be 7.5 and 5.1 mm, respectively. They also observed the ligament to be straight at the midline with no fanning between the attachment points. They did not observe any connection between the alar and cruciform ligaments, and the tectorial membrane.

An area between the apical ligament and the superior extension of the cruciform ligament was routinely found to be filled with connective tissue, fat, and a small venous plexus. Interestingly, they found the ligament to be present in only 80 % of the cadavers. The alar ligaments extend from the tip of the dens to the medial aspects of each occipital condyle, with a small insertion also on the lateral mass of the atlas [30]. They average 10.3 mm long and run from the posterolateral aspect of the odontoid process, laterally forming an angle ranging from 125° to 210° with a mean of 154° [25]. An MR imaging study conducted by Baumert et al. [31] found that the alar ligament was oriented caudocranially in 67 % of the cases and horizontally in 33 %. The alar ligaments function as stabilizing structures of the atlantoaxial joint and act to limit axial rotation and lateral bending to the contralateral side. They are the only ligaments, except the transverse ligament, which are strong enough to stabilize the craniocervical junction and prevent anterior displacement of the atlas. If the transverse ligament ruptures, the alar ligaments become responsible for preventing atlantal subluxation. Fielding et al. [27] reported that the alar ligaments alone are not as strong as the transverse ligament. The alar ligaments serve as secondary restrictions of the atlas to anterior shift [27]. Following the rupture of the transverse ligament, a mean force of 72 kg was needed to stretch the alar ligament to create a predental space of 12 mm, and any subluxation greater than 12 mm caused the alar ligament to rupture. Similarly, Dvorak et al. [30] noted that the transverse ligament could withstand a load of 350 N, whereas the alar ligament could only withstand 200 N before rupturing. The alar ligament limits the axial rotation on the contralateral side to about 90°. Sometimes there is a ligamentous connection between the base of the dens and the anterior arch of the atlas (anterior atlantodental ligament) . In a recent work by Tubbs et al. [32], the anterior atlantodental ligament was found in 81.3 % of 16 specimens

dissected. The attachment of each ligament was consistent and travelled between the base of the anterior dens to the posterior aspect of the anterior arch of the atlas in the midline and just inferior to the fovea dentis. The ligament was roughly 4 × 4 × 4 mm in all specimens.

The tectorial membranes extend from the posterior body of the axis and the posterior longitudinal ligament to the upper surface of the basilar portion of the occipital bone and the anterior aspect of the foramen magnum. This membrane covers all other occipitoaxial ligaments as well as the dens. Thus, anterior to the spinal canal at the level of the craniocervical junction, the ligaments are arranged with the anterior atlantooccipital membrane most anteriorly followed (in an anterior-to-posterior direction) by the apical, the alar, and the cruciate and, most posteriorly, the tectorial [1]. The tectorial membrane firmly adhered to the cranial base and body of the axis but not to the posterior odontoid process [24]. Other ligaments have been remembered and described in recent publications by Tubbs et al. [25, 33].

The transverse occipital ligament (TOL) is a small accessory ligament of the craniovertebral junction that is located posterosuperior to the alar ligaments and odontoid process. It attaches to the inner aspect of the occipital condyles, posterosuperior to the alar ligament, superior to the transverse ligament, and extends horizontally across the foramen magnum. Tubbs et al. [33] have identified it in 7 (77.8 %) of 9 human cadavers. Dvorak et al. [34] stated that the TOL was only present in about 10 % of the population, whereas Lang [35] identified the TOL in approximately 40 % of their specimens. The discrepancies in the occurrence of the TOL in specimens could be due to the proximity and similar morphology to the alar ligament. Clinically, the TOL may be encountered during a transoral odontoidectomy.

The Barkow's ligament, rarely described, is a horizontal band attaching onto the anteromedial aspect of the occipital condyles anterior to the attachment of the alar ligaments. This ligament is located just anterior to the superior aspect of the dens with fibers traveling anterior to the alar ligaments, but there is no attachment to these structures. Tubbs et al. [36] found the ligament to be present in 12 (92.3 %) of 13 cadavers, observing an attachment between the Barkow's ligament and the anterior atlantooccipital membrane at the midline in 9 specimens (75 %).

The articulation between the axis and the third vertebra has the same anatomic characteristics of the subaxial cervical spine. The bodies of the cervical vertebrae are connected by two longitudinal ligaments and the intervertebral disks. The anterior longitudinal ligament is a broad, thick ligament that runs longitudinally anterior to the vertebral body and disk. It is joined loosely to the periosteum of the anterior vertebral bodies and closely to the annulus fibrosus of the anterior vertebral disk and attaches superiorly to the anterior tubercle of the atlas.

The posterior longitudinal ligament (PLL) lies within the vertebral canal on the posterior aspect of the vertebral bodies and intervertebral disks. Superiorly, it is continuous with the tectorial membrane and thus attaches to the occipital bone and anterior aspect of the foramen magnum. As it descends, it narrows behind each vertebral body but spreads out at the disk level, where it is adherent to the annulus fibrosis.

2.3 Neural Elements

The spinal cord extends from the foramen magnum above, where it is continuous with the medulla oblongata. With its surrounding meninges, it lies within the vertebral or spinal canal, which is formed by sequential vertebral foramina. The anterior wall of the spinal canal is formed by the posterior border of the intervertebral disks and cervical vertebral bodies. The lateral wall consists of the pedicles and successive intervertebral foramina, through which the spinal nerves exit. Posteriorly, the articular processes laterally and the ligamentum flavum and the lamina medially and posteriorly form the final borders of the spinal canal [1].

The first cervical spinal nerve exits between the occiput and the atlas through an orifice in the posterior atlantooccipital membrane just above

the posterior arch of the atlas and posteromedial to the lateral mass of the atlas. Just beyond the dorsal root ganglion and usually just outside the intervertebral foramina, the cervical spinal nerves divide into dorsal and ventral primary rami. Its ventral primary ramus unites with the second cervical ventral primary ramus and contributes fibers to the hypoglossal nerve(this is also known as the superior root of the ansa cervicalis); the dorsal primary ramus of the C1 nerve root—also known as the suboccipital nerve—enters the suboccipital triangle and innervates the muscles of this region. It has usually no cutaneous branch [1, 37, 38].

The second cervical nerve emerges between the posterior arch of the atlas and the lamina of the axis just posterior to its lateral mass (Fig. 2.7). Its dorsal rami are much larger than its ventral rami and are the largest of all the cervical dorsal rami. The medial branch of the dorsal rami, or greater occipital nerve, runs transversely in the soft tissue dorsal to axis' lamina, turning cranial around the muscle belly of the obliquus capitis inferior muscle, piercing the semispinalis capitis muscle, and then eventually entering the scalp with the occipital artery through an opening above the aponeurotic sling between the trapezius and the stemocleidomastoid.

2.4 Vertebral Artery

The major source of blood for the osseous and neural elements of the cervical spine is the vertebral arteries, which arise from the first part of the subclavian artery medial to the scalenus anterior and ascend behind the common carotid artery between the longus colli and the scalenus anterior. They are crossed by the inferior thyroid artery and on the left by the thoracic duct. In the lower cervical region, they lie anterior to the ventral rami of the seventh and eight cervical nerves and to the transverse process of the seventh cervical vertebra. The vertebral artery usually enters the transverse foramen of C6 and ascends through the transverse foramina from C6 through the axis, in front of the ventral rami of the cervical nerves. In this region, they lie within a fibro-osseous tunnel, fixing it to adjacent structures via a trabeculated collagen network. Vertebral arteries are surrounded by a venous plexus and sympathetic nerve fibers [1, 39].

At the level of the atlas, the vertebral arteries pass through the vertebral foramen of the atlas and travel posteriorly and medially behind the lateral mass and then superiorly from the posterior arch of the atlas. As mentioned, in 1–15 % of the population, a bony arch may form, thereby

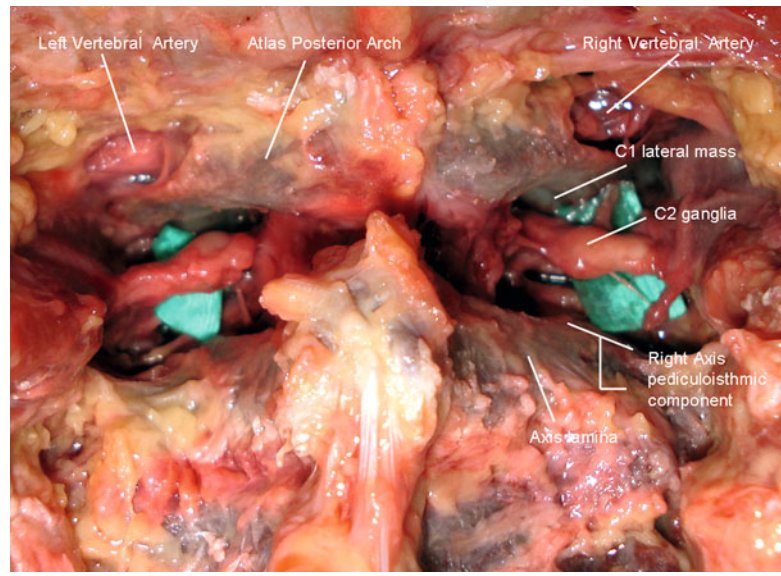


Fig. 2.7 Dissection of the posterior aspect of C1–C2 showing vertebral artery and the second cervical nerve and ganglia

converting this groove into the arcuate foramen [3]. The arteries then pierce the posterior atlantooccipital membrane, turning anteriorly and cephalad through the foramen magnum joining to form the basilar artery. Just before forming the basilar artery, the vertebral arteries give off branches anteriorly that join to form the single anterior spinal artery. This artery runs within the anterior median fissure of the spinal cord, providing blood supply to roughly the anterior two-thirds of the spinal cord.

The posterior third of the spinal cord is supplied by two posterior spinal arteries, which arise from either the vertebral artery or the posterior inferior cerebral arteries. The nerve roots are supplied by radicular branches from the spinal arteries. Anomalies of the vertebral artery in the region of C1–C2 include fenestration or intraspinal coursing and have been found to have a prevalence of 0.3–2 % [40]. In patients having osseous anomalies at the craniovertebral junction, the frequency of vertebral artery anomalies at the extraosseous and intraosseous regions is increased. With preoperative three-dimensional computed tomography angiography, we can precisely identify the anomalous vertebral artery and reduce the risk of intraoperative injury to the vertebral artery [41].

The blood supply of the cervical vertebral bodies originates from segmental vessels off the vertebral arteries. At each level, these branches exit, passing anteriorly beneath the longus colli, supplying the anterior vertebral body and the anterior longitudinal ligament. Another branch enters the intervertebral foramina and passes anteriorly and superiorly, supplying the posterior vertebral body and the posterior longitudinal ligament. Other branches pass laterally from within the spinal canal, supplying the laminae and radicular branches to the spinal cord. The outer surface of the laminae is supplied by other branches of the vertebral artery that pass dorsally before entering the intervertebral foramina [1].

The vascular supply to the odontoid process is unique and worth mentioning. It is supplied by paired ascending anterior and posterior arteries, all of which arise from the vertebral arteries. These arteries rise along the borders of the dens to form an apical arcade, which anastomoses with the carotid system via anterior and posterior horizontal arteries [39, 42, 43] (Fig. 2.8). The alar and accessory ligaments also make vascular contributions, as does an intraosseous supply from the body of the axis. Whereas the clinically observed problem of non-union of fractures of the odontoid process has been attributed to a scant blood supply, this does not appear to be the primary causative factor [4]. Venous drainage of the cervical spine occurs through internal and external venous plexi. The external veins run paired with the arteries described earlier. The internal plexus lies within the spinal canal and consists of a valveless series of epidural sinuses. This complex of veins is continuous from the cerebral sinuses distally to the pelvis. These veins are most prevalent at the vertebral bodies and thinnest at the disk spaces. They drain through the intervertebral foramina into the cava and azygos systems [39].

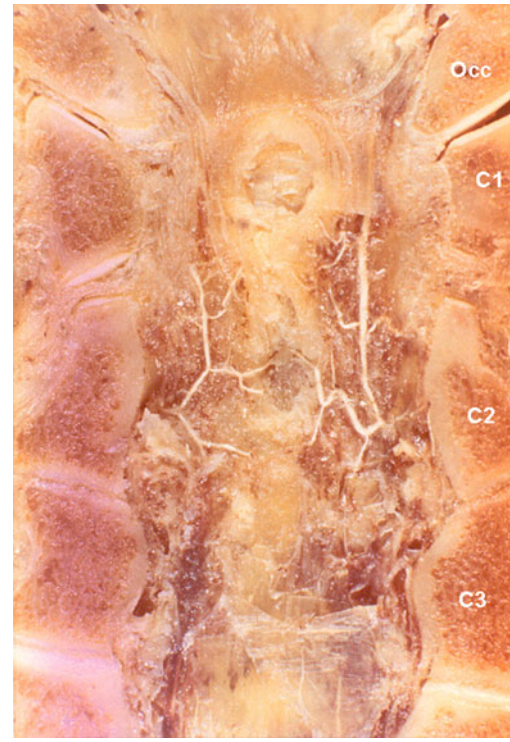


Fig. 2.8 Posterior view of the vasculature of the odontoid process (Courtesy of Prof. R. Ramón-Soler)

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