

VERTEBRAL ARTERY

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1. Core Definition and Significance

The **vertebral artery** (VA) is one of the major arteries of the neck, playing a critical role in supplying blood to the brain, particularly the posterior circulation system. It is a paired structure, meaning there is one vertebral artery on the left side and one on the right side of the body. These arteries originate from the respective subclavian arteries, typically ascending through specialized bony channels within the cervical spine before entering the cranium. The vertebral arteries are essential for providing oxygenated blood to the brainstem, cerebellum, and the posterior cerebral hemispheres. Their integrity is paramount for maintaining balance, coordination, and vital autonomic functions, rendering them highly significant in clinical neurology and cerebrovascular health.

Unlike the common carotid arteries, which travel anteriorly, the vertebral arteries take a highly protected, deep course, shielded by the cervical vertebrae, which grants them anatomical stability but also exposes them to potential injury during severe neck trauma or sudden, extreme neck movements. The complex pathway of the vertebral artery, involving sharp turns and passage through narrow bone tunnels, makes it uniquely vulnerable to mechanical compression or dissection, leading to critical conditions such as posterior circulation strokes. The ultimate function of these paired vessels is to converge to form the **basilar artery**, establishing the primary inflow pathway for the posterior circulation of the brain, which interfaces directly with the arterial network known as the Circle of Willis.

2. Anatomical Course and Segments (V1-V4)

The anatomical journey of the vertebral artery is conventionally divided into four distinct segments, V1 through V4, based on the structures they traverse, a classification highly relevant for surgical planning and radiological interpretation. The first segment, known as the **pre-vertebral segment (V1)**, begins at its origin from the superior aspect of the subclavian artery, often traveling upward and slightly medially to enter the transverse foramen of the C6 vertebra. This segment is susceptible to compression by structures in the lower neck region, although it is generally the least protected part of the artery's course before it enters the bony spine. Anatomical variations in the V1 segment are common, including differing origins (e.g., directly from the aorta) or entry points (C5 or C7).

The second segment, the **cervical or foraminal segment (V2)**, is perhaps the most characteristic portion of the vertebral artery's path. It ascends vertically through the transverse foramina of the

cervical vertebrae, typically running from C6 up to the C2 vertebra. During this ascent, the artery is accompanied by the vertebral vein and sympathetic nerve fibers, forming the neurovascular bundle within the bony canal. The protection offered by the surrounding bone limits external compression but makes the artery vulnerable to pathology or trauma involving the cervical spine, such as severe degenerative changes or fractures. The V2 segment is crucial because its proximity to the spinal nerve roots means that bony spurs or instability can potentially cause symptoms related to both vascular and neurological compromise.

The third segment, the **Atlantic or suboccipital segment (V3)**, spans the distance between the transverse foramen of C2 (axis) and the entry point into the dura mater at the base of the skull. This segment is marked by two distinctive and sharp curves, granting it increased mobility necessary for head rotation. After exiting C2, the artery courses laterally and posteriorly to enter the transverse foramen of C1 (atlas), then curves medially behind the lateral mass of C1, running along the posterior arch of the atlas within the suboccipital triangle before piercing the posterior atlanto-occipital membrane. The tortuosity of the V3 segment, often referred to as a "loop" or "S-curve," makes it particularly susceptible to stretching, kinking, or dynamic compression during extreme head rotation, a mechanism involved in certain types of **vertebral artery dissection (VAD)**.

Finally, the fourth segment, the **intracranial segment (V4)**, begins as the artery pierces the dura mater and arachnoid membrane, entering the skull through the **foramen magnum**. This segment travels upward and anteriorly, hugging the medulla oblongata on its ventral surface. Within the V4 segment, the vertebral artery gives off critical branches, including the posterior inferior cerebellar artery (PICA), which supplies a vital portion of the cerebellum and brainstem. The V4 segments of the left and right vertebral arteries converge at the lower border of the pons to definitively form the unpaired basilar artery, completing the initiation of the basilar system.

3. Physiological Function and Blood Supply

The primary physiological function of the vertebral artery is to maintain continuous and adequate perfusion of the posterior fossa structures and, subsequently, the posterior cerebrum. The structures supplied by the vertebral artery system are responsible for many fundamental neurological functions, including consciousness, respiration, cardiac regulation, balance, and fine motor coordination. This makes the vertebral artery system indispensable for survival and quality of life. The blood pressure and flow through these arteries are tightly regulated by autonomic mechanisms, responding dynamically to metabolic needs and postural changes.

While ascending, the vertebral artery provides numerous small branches that supply local tissues, including muscular branches to deep neck muscles and spinal branches that enter the vertebral canal to supply the spinal cord and its surrounding structures. However, its most critical

contributions occur within the V4 segment. The most significant branch is the **Posterior Inferior Cerebellar Artery (PICA)**, which is variable in its origin but typically arises just before the vertebral arteries merge. PICA supplies the inferior surface of the cerebellum, the choroid plexus of the fourth ventricle, and the lateral medulla, which is the site of several crucial cranial nerve nuclei and tracts. Ischemia in the PICA distribution is clinically recognized as Wallenberg Syndrome (Lateral Medullary Syndrome), characterized by a unique constellation of neurological deficits.

4. Formation of the Basilar Artery and Posterior Circulation

The convergence of the two V4 segments of the vertebral arteries at the junction between the medulla and the pons marks the formation of the single, median **basilar artery**. This merger point is a crucial anatomical landmark, as the basilar artery becomes the sole conduit for blood flow to the midbrain, pons, and upper cerebellum. The basilar artery ascends the clivus, supplying key structures via paired branches, including pontine arteries, superior cerebellar arteries (SCA), and anterior inferior cerebellar arteries (AICA).

The basilar artery terminates by bifurcating into the paired **posterior cerebral arteries (PCA)**. These PCAs are the final output of the posterior circulation and are responsible for supplying the temporal lobes, occipital lobes (the primary visual cortex), and parts of the thalamus. This posterior circuit, often referred to as the vertebrobasilar system, is functionally integrated with the anterior circulation (supplied by the carotid arteries) via the posterior communicating arteries (PCoA), forming the complete **Circle of Willis**. The existence of the Circle of Willis provides collateral circulation, meaning that if one major feeding artery, such as one vertebral artery, is occluded, blood may still reach vital areas via alternative pathways, though the capacity of this collateral flow varies significantly among individuals.

5. Clinical Pathology: Vertebral Artery Dissection (VAD) and Stroke

Clinical conditions involving the vertebral artery are frequently serious due to its role in posterior circulation. One of the most critical pathologies is **Vertebral Artery Dissection (VAD)**, which occurs when a tear forms in the inner lining (intima) of the arterial wall, allowing blood to flow into the wall layers, separating them. This intramural hematoma can either narrow the vessel lumen, leading to **ischemic stroke**, or form an aneurysm that can rupture. VAD is a leading cause of stroke in young and middle-aged adults, often triggered by minor trauma, such as chiropractic manipulation, intense physical exertion, or abrupt, forceful movements of the neck that stress the V3 segment.

Symptoms of VAD typically include severe, persistent head and neck pain, often localized to the occipital region, which may precede neurological symptoms by hours or days. When VAD leads to occlusion or embolism, the resulting stroke manifests as **Vertebrobasilar Insufficiency (VBI)**. VBI

symptoms include vertigo, dizziness, diplopia (double vision), ataxia (loss of coordination), and unilateral weakness. Since the posterior circulation supplies the brainstem, VBI can severely impair vital centers controlling consciousness, breathing, and heart rate. Atherosclerosis, though more common in older patients, can also affect the vertebral arteries, particularly at their origin from the subclavian artery or at the V4 segment, narrowing the lumen and predisposing the patient to thrombotic events.

6. Diagnostic Imaging and Assessment

Accurate assessment of the vertebral artery is essential for diagnosing VAD, VBI, and planning interventions. Several non-invasive and invasive imaging modalities are employed. **Doppler ultrasonography** is often the first-line non-invasive assessment, particularly for evaluating flow dynamics and detecting proximal stenosis (narrowing) at the V1 segment. It is useful for screening but lacks the resolution required for detailed analysis of the V2 and V3 segments deep within the bony spine.

The gold standard for non-invasive, high-resolution visualization is **Computed Tomography Angiography (CTA)** or **Magnetic Resonance Angiography (MRA)**. CTA provides excellent visualization of the bony canal and the artery's relationship to the surrounding vertebrae, which is critical in trauma or spinal instability. MRA is superior for visualizing the arterial wall itself, aiding in the diagnosis of dissection by revealing intramural hematomas or flap formation, and is generally preferred for non-acute assessment. Invasive **Digital Subtraction Angiography (DSA)** remains the definitive diagnostic tool, used primarily when endovascular treatment is planned or when non-invasive imaging is inconclusive, providing highly detailed, real-time visualization of the lumen and collateral flow patterns.

7. Surgical and Interventional Considerations

Surgical intervention for the vertebral artery is complex due to its deep and protected location. In cases of significant stenosis at the origin (V1 segment) leading to recurrent VBI or 'subclavian steal syndrome' (though less common than carotid disease), vascular surgeons may perform a bypass graft or a **transposition procedure** to reroute flow from the vertebral artery to a healthy major vessel. Endovascular techniques, such as balloon angioplasty and stenting, are increasingly utilized for treating severe atherosclerotic stenosis in the V1 segment, providing a less invasive alternative to open surgery.

In the context of spinal surgery, particularly complex instrumentation of the upper cervical spine (C1-C2), precise knowledge of the vertebral artery's course is crucial. Misplaced screws or instrumentation trajectories can result in catastrophic bleeding or acute stroke due to direct arterial injury. Pre-operative CTA is mandatory for identifying anatomical variations, such as the artery

entering at C4 instead of C6, or a highly medially looping V3 segment, ensuring that the planned surgical trajectory avoids vascular compromise. Management of VAD typically involves anticoagulation to prevent thromboembolism, but surgery or endovascular therapy may be necessary if the dissection leads to flow-limiting pseudoaneurysm formation or persistent critical ischemia.

Further Reading

[Vertebral Artery \(Wikipedia\)](#)

[Vertebral Artery Dissection: Pathophysiology, Clinical Presentation, and Treatment \(AHA Journals\)](#)

[Anatomy and Clinical Implications of the Vertebral Artery \(NCBI/PMC\)](#)

[Circle of Willis \(Wikipedia\)](#)

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