

Vertebral Artery Surgery – An Overview of Techniques and Discussion Points for the Future

Bernard George

Professor of Neurosurgery, Hospital Lariboisière, Paris

Abstract

The vertebral artery (VA) is an important vessel supplying the hind brain; its surgical exposure and control is usually considered a great challenge. In fact, with good knowledge of surgical anatomy and proper surgical technique, the VA can be controlled and occasionally repaired with safety and reliability. VA exposure is useful in many instances and helps attain better results in the surgical treatment of many different pathologies at any level all along its course in the neck and the skull. These pathologies include intrinsic lesions (atherosclerosis, aneurysms, arteriovenous fistulas), intermittent compression by osteophytes or fibrous bands, and permanent compression mostly by different types of tumours. VA exposure also helps to achieve better treatment of spondylotic myelopathy (by oblique corpectomy) and of tumours at the craniocervical junction, foramen magnum and jugular foramen level. Based on the experience of more than 1,600 surgical approaches, VA surgery is associated with a very limited morbidity and mortality.

Keywords

Vertebral artery, surgery, lateral approaches, vertebro-basilar ischaemia, cervical tumours, craniocervical junction

Disclosure: The author has no conflicts of interest to declare.

Received: 16 May 2011 **Accepted:** 25 July 2011 **Citation:** *European Neurological Review*, 2011;6(3):193–5 DOI:10.17925/ENR.2011.06.03.193

Correspondence: Bernard George, Service de Neurochirurgie, Hôpital Lariboisière, 2, rue Ambroise Paré, 75475 Paris Cedex 10, France. E: bernard.george@lrp.aphp.fr

The vertebral artery (VA) is a branch of the subclavian artery, which runs along the cervical spine and ends intradurally at the junction with the basilar trunk. It is subdivided into four segments: V1 segment (ostial segment) from origin to C6, V2 segment (transversary segment) from C6 to C2, V3 segment (suboccipital segment) from C2 to the dura mater of the foramen magnum (FM) and V4 segment (intradural segment) from FM dura to the vertebrobasilar junction.^{1–3} Many variations and anomalies, though rare, must be recognised. Among them, the most frequent are atretic or hypoplastic VA (minor VA), abnormal level of entrance into the transversary canal (C7, C5, C4 or C3 instead of C6), loops, duplication, intradural course, extracranial origin of the posterior inferior cerebellar artery (PICA) and proatlantal artery.⁴

Surgical Exposure

The most adequate approach is the anterolateral approach, which basically passes between the internal jugular vein (IJV) and the sternomastoid muscle (SM)^{1–3} (see *Figure 1*). The patient is in the supine position and the skin incision follows the medial edge of the SM at the adequate level. For the V1 and V3 segments it is often useful to detach the SM muscle respectively from the clavicle and the mastoid process. All the vasculo-nervous elements, trachea and oesophagus are retracted medially. In the depth of the field, the sympathetic chain must be identified and generally retracted laterally. The longus colli and sometimes the longus capitis muscles must be divided and resected along the transverse processes and lateral aspect of the vertebral bodies. The transverse processes are then resected subperiosteally so as to keep the VA and venous plexus inside their periosteal sheath. To keep working as much as possible

out of this periosteal sheath is the key for a safe exposure and control of the VA. The only element crossing the field is the accessory nerve above C3. The general principle, whatever the pathology, is VA control proximal and distal to the lesion before going to it.

Morbidity is limited to Horner's syndrome (2 %), and exceptionally to pain in the shoulder (accessory nerve); VA rupture or tear (seven out of 1,650) is possible when encased in tumours, needing its repair in case of dominant vessel (three times).^{1–3}

Indications

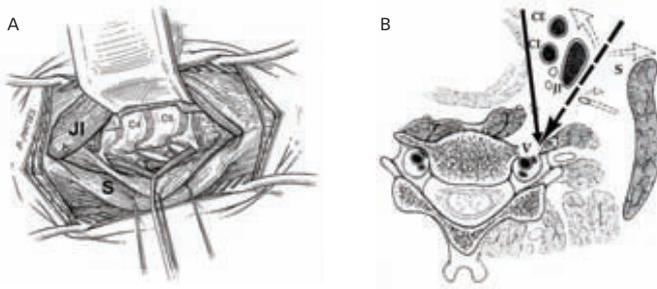
Intrinsic Lesions

Intrinsic lesions include atherosclerotic stenosis and occlusion, aneurysms and arteriovenous fistulas. Most often nowadays indications of surgical revascularisation are an exception, since endovascular treatment is more appropriate.^{5,6} However, in a few cases, surgical revascularisation has to be realised either by VA reimplantation onto the carotid artery or subclavian artery or by a saphenous vein graft bypass.

Extrinsic Compressions

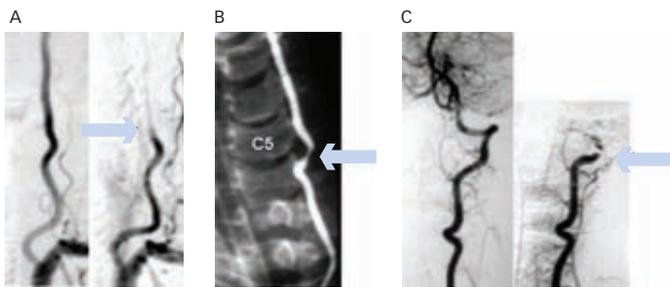
Permanent compression is observed in the case of tumours but is never symptomatic, since the slow tumoural growth gives time for collateral development, even in cases of occlusion. Conversely, intermittent VA compression, although very rare, may be observed in relation with osteophytes (C4–C5 and C5–C6 levels), fibrous bands at the entrance of the VA into the transverse canal and at the V3 level and bony malformation of the craniocervical junction (CCJ)^{7,8} (see *Figure 2*). In fact, symptoms always occur during the same particular movement

Figure 1: Schematic Drawings of the General Principles of the Lateral Approach



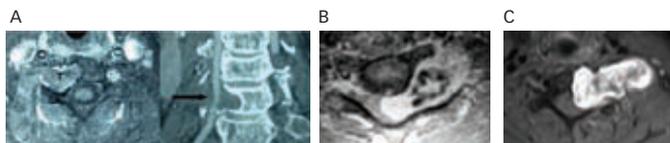
On the left (A) exposure at the level of the V2 vertebral artery (V) segment with opening of the field between the internal jugular vein (JI) and the sternomastoid muscle (S). On the right (B) comparison between the anterior approach (black line) opening the field medial to the external and internal carotid arteries (CE and CI), and the lateral approach (dotted line) opening the field between the internal jugular vein (JI) and the sternomastoid muscle (S).

Figure 2: Three Examples of Vertebral Artery External Compression (Arrows)



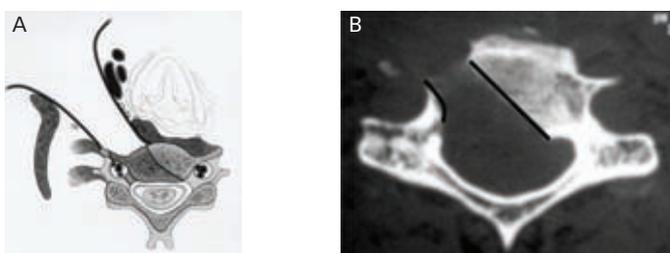
A: Osteophytes at the C5-C6 level. B: Fibrous bands at the C5 level. C: Fibrous bands at the C1-C2 level.

Figure 3: Three Examples of Neurinomas Developed in the Vicinity of the Vertebral Artery



A: Left: axial magnetic resonance image (MRI) showing an extraspinal neurinoma (T); right: computed tomography angiograph (AngioCT) showing the defect in the vertebral body and the vertebral artery A (black arrow). B: Intradural, foraminal and extraspinal Schwannoma at C6-C7. C: Intradural, foraminal and extraspinal neurofibroma at C5-C6.

Figure 4: Oblique Corpectomy



A: Schematic of the principle of oblique drilling of the posterolateral corner of the vertebral body. B: Post-operative computed tomography (CT) scan showing the result of an oblique corpectomy.

of the head and neck and this movement also induces a severe stenosis or an occlusion of the VA, shown by different imaging techniques: Doppler, computed tomography angiography (angioCT), magnetic resonance angiography (angioMR) and/or angiography. These intermittent compressions are essentially observed at the two

levels where the VA adventitia is fixed to the periosteum or the dura: at the entrance into the transverse canal and especially in cases of abnormal level of entrance; and at the V3 level. Surgical decompression necessitates the release of the bony and fibrous compressive elements with opening of the proximal and distal transverse foramen.

Tumours Related to the Vertebral Artery

Tumours growing in the vicinity of the VA may displace, compress and even occlude the VA. Control of the VA proximal and distal to the tumour allows a safe and more complete resection with, most of the time, VA preservation. Another advantage of VA control in a first step is to divide the vascular supply in case of highly vascular tumours.^{1-3,9}

These tumours are essentially of two types. First, neuromeningeal tumours with neurinomas (Schwannomas and neurofibromas) as the most common type but also meningiomas, haemangioblastomas and paragangliomas. These types of tumours develop along the cervical nerve roots and are therefore located in the intervertebral foramen (hour glass tumours) with possible intraspinal (extra- and intradural) and extraspinal extensions (see Figure 3). Any of these tumoural parts (even the intradural part) can be reached by the anterolateral approach using the corridor given by the enlarged intervertebral foramen; further widening of this foramen may be achieved by limited drilling of the posterolateral corner of the vertebral bodies. Second are bone tumours, benign or malignant such as chordomas, osteoblastomas, osteochondromas, metastasis, etc. When these tumours originate in the lateral part of the vertebral bodies, they may involve and even encase the VA. In some malignant tumours, radical resection may demand sacrifice of the VA. This may be carried out after a balloon occlusion test; in case of dominant VA and a non-tolerated test, a revascularisation must be realised. In any case, the lateral approach is a more direct route to the tumour that reduces the extent of bone drilling and simplifies and sometimes avoids vertebral body reconstruction.

Oblique Corpectomy

This technique includes the drilling of the posterolateral corner of one or several vertebral bodies;¹⁰ at its maximum, it can be extended up to the opposite pedicle (see Figure 4). Therefore, this technique provides a nice decompression of the anterior aspect of the spinal cord. It is mostly used in cases of spondylotic myelopathy with collapsed discs. More than half of the vertebral bodies are preserved and as a consequence no fixation procedure (grafting of osteosynthesis) is required. Another advantage is the possibility of achieving a real nerve root decompression alone or associated with the spinal cord decompression. In fact the anterolateral approach is the only route that permits following the entire length of the cervical nerve root.

Craniocervical Junction¹⁻³

At this level, the anterolateral approach provides access to half the circumference of the CCJ from the posterior midline to the anterior midline. It is mostly used for extradural and bony lesions such as chordomas,¹¹ osteochondromas, metastases, eosinophilic granulomas, synovial cysts and other degenerative or inflammatory processes. Exposure of the VA is more difficult as it corresponds to the V3 segment, which has a complex course around the joints C0-C1 (occipital condyles-lateral mass of atlas) and C1-C2. The same subperiosteal dissection must be applied to control the VA with opening of the C1 and sometimes C2 transverse foramen. Moreover, in some cases, it may be necessary to transpose the VA out of the C1

transverse foramen. The very lateral access given by this approach reduces the need for bone drilling, especially of the occipital condyle and lateral mass of atlas, and sometimes of a fixation procedure.¹² Iatrogenic instability should be rare.

Another option at the CCJ level is the posterolateral approach, which is the lateral enlargement of the midline posterior approach with exposure of the VA in its groove over the posterior arch of atlas.¹³ This approach is essentially designed for intradural tumours of the foramen magnum including mostly meningiomas and neurinomas^{14,15} (see *Figure 5*). Resection of these tumours using the posterolateral approach is complete in almost every patient at first presentation. Lateral access with division of the first arch of the denticulate ligament and of the first cervical nerve root permits working in front of the neuraxis (spinal cord and medulla oblongata) without any retraction.

Jugular Foramen Tumours

The anterolateral approach combined with a retrosigmoid approach allows exposure of the upper part of the internal jugular vein (IJV) and the distal part of the sigmoid sinus. In between them is the jugular bulb inside the JF covered by the jugular tubercle. This is called the juxtacondylar approach.¹⁶ In the case of tumours developed strictly inside the JF like Schwannomas, this approach is quite sufficient for a total removal with preservation of the intact lower cranial nerves. In fact the most frequent tumours at the JF level are paragangliomas (glomus jugulare tumours), which generally extend out of the JF into the petrous bone. In this case some drilling of the petrous bone is obviously necessary but may be limited; in almost every case, the facial nerve should not be transposed and whenever possible kept inside its bony canal. Compared with the transpetrosal approach this is a major advantage. As a matter of fact VA control in its V3 segment gives access to the JF from posteriorly and inferiorly; this explains why the superior approach to the JF through the petrous bone can be reduced.¹⁶⁻¹⁸

Overall, it is quite possible, safe and useful to expose and control the VA anywhere in the neck. There is no reason to consider the VA as a particular vessel. Like any other vessel, its exposure has its own particularities but with a good knowledge of the anatomy and some training, it is a reliable technique. The main concern about the VA is the perivertebral venous plexus and consequently troublesome venous bleeding. Preserving these veins with the VA in their surrounding periosteal sheath is a good way to keep out of trouble. Moreover, if any troublesome venous bleeding occurs, several products quite efficient in the control of venous bleeding

Table 1: Distribution of Pathologies Requiring Vertebral Artery Surgery

Pathology	Numbers
Intrinsic lesions (bypass and re-implantation):	152
Intermittent external compression:	17
Tumours of the V1 and V2 segments:	296
Oblique corpectomy:	612
Foramen magnum tumours:	186 (137 meningiomas)
Cranio-cervical junction tumours:	268 (75 chordomas)
Jugular foramen tumours:	122
Total:	1,653

Figure 5: Foramen Magnum Tumours



A and B: Foramen magnum meningioma. The arrow indicates the axis of work.

C: Large extradural Schwannoma at the C1–C2 level; the arrow indicates the contralateral vertebral artery.

have recently been produced; therefore, there is today no reason to keep a blind corner around the transverse processes and intervertebral foramina in surgery on the cervical spine.

Today, every part of the VA in the neck has been investigated and for many different pathologies. It must be expected that VA surgery will become more popular among spine surgeons and that residual tumour near the VA responsible for repeated recurrences will no longer be acceptable. On the technical aspects, the use of the endoscope and neuro-navigation may permit in some cases further reduction of the invasiveness of this surgery. More safety and comfort is already available with the use of filter microscopes, which allows visualisation of the flow inside vessels and should help for better preservation of the VA.

Conclusion

Over the last 30 years more than 1,600 surgical exposures of the VA (see *Table 1*) have been achieved in Lariboisiere Hospital with very limited morbidity. It has greatly enlarged the possibilities of treatment of many cervical and intracranial lesions. New technological tools (neuro-navigation, endoscopy, haemostatic agents) should help to develop and make available this surgery in every hand. ■

- George B, Blanquet A, Alves O, Surgical exposure of the vertebral artery, In: *Operative Techniques in Neurosurgery*, New York: WB Saunders, 2001;168–81.
- George B, Extracranial vertebral anatomy and surgery, In: *Advances and Technical Standards in Neurosurgery*, New York: Springer Verlag, 2002;27:179–216.
- George B, Bruneau M, Spetzler RF, *Pathology and Surgery around the Vertebral Artery*, Paris: Springer Verlag, 2011;677.
- Bruneau M, Cornélius JF, Marneffe V, George B, Anatomical variations of the V2 segment of the vertebral artery, *Neurosurgery*, 2006;59:20–4.
- Berguer R, Flynn LM, Kline RA, Caplan L, Surgical reconstruction of the extracranial vertebral artery: management and outcome, *J Vasc Surg*, 2000;31:9–18.
- Albuquerque FC, Fiorella D, Han P, A reappraisal of angioplasty and stenting for the treatment of vertebral origin stenosis, *Neurosurgery*, 2003;53:607–14.
- Sorensen BF, Bow Hunter's stroke, *Neurosurgery*, 1978;2:259–61.
- George B, Laurian C, Impairment of vertebral artery flow caused by extrinsic lesions, *Neurosurgery*, 1989;24:206–14.
- Lot G, George B, Cervical neuromas with extradural components: surgical management in a series of 57 patients, *Neurosurgery*, 1997;41:813–20.
- Bruneau M, Cornélius JF, George B, Multilevel oblique corpectomies: surgical indications and technique, *Neurosurgery*, 2007;61(Suppl 3):106–12.
- Carpentier A, Polivka M, Blanquet A, George B, Suboccipital and cervical chordomas: the value of aggressive treatment at first presentation of the disease, *J Neurosurg*, 2002;97:1070–7.
- Lot G, George B, The extent of drilling in lateral approaches to the cranio-cervical junction area from a series of 125 cases, *Acta Neurochirurgica (Wien)*, 1999;141:111–8.
- Bruneau M, George B, Foramen magnum meningiomas: detailed surgical approaches and technical aspects at Lariboisiere Hospital and review of the literature, *Neurosurg Rev*, 2008;31(1):19–34.
- George B, Lot G, Neurinomas of the two first cervical nerve roots: a series of 42 cases, *J Neurosurg*, 1995;82:917–23.
- Samii M, Klekamp J, Carvalho G, Surgical results for meningiomas of the cranio-cervical junction, *Neurosurgery*, 1996;39:1086–94.
- Bruneau M, George B, The juxtacondylar approach to the jugular foramen, *Neurosurgery*, 2008;62:75–81.
- Pellet W, Cannoni M, Pech A, The widened transcondylar approach to jugular foramen tumors, *J Neurosurg*, 1988;69:887–94.
- Fisch U, Infratemporal fossa approach to tumors of the temporal bone and base of the skull, *J Laryngol Otol*, 1978;92:949–67.