Surgery Involving the Vertebral Artery at the Cranio-vertebral Junction

28

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28.1 Introduction

The ability to surgically expose and control the vertebral artery (VA) in its third segment (V3) between C2 and the foramen magnum (FM), e.g., at the level of the cranio-vertebral junction (CVJ), is very useful as it permits to treat many problems; they include intrinsic occlusive VA diseases or extrinsic compression during particular movements of the head and neck, also named Bow Hunter's syndrome inducing vertebro-basilar ischemia, but also and mainly, many tumors that are also better treated using surgical approaches in which the VA exposure is part of the technique: FM, CVJ, and Jugular Foramen (JF) tumors [1–8].

All these pathologies need surgical approaches that include VA exposure but also specific techniques. In this chapter, the surgical exposure of the VA will be first described, and then the associated specific techniques necessary to treat all the previously mentioned pathologies will be reported.

For a better understanding, the reader is invited to previously read the chapter: Anatomy of the VA third segment.

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28.2 VA Exposure

The VA at the CVJ level can be exposed by two surgical approaches: the posterolateral and the anterolateral approach [2, 9]. After the initial description [10], they were published with some variations under different names, especially the far lateral and the extreme lateral [11–20].

28.2.1 Posterolateral Approach

The posterolateral approach (Fig. 28.1a) is a lateral extension of the standard midline posterior approach. The patient is most of the time placed in the prone position but some surgeons sometimes favor the lateral or the sitting position. The midline skin incision extends from the occipital protuberance down to the C4-C5 level and curves laterally along the superior occipital crest more or less toward the mastoid process following the size and shape of the neck. Some surgeons prefer a paramedian or an oblique straight or S shape incision. The advantage of the midline and superiorly curved skin incision is to start by a midline exposure which is familiar to everyone; then the muscles are detached from the superior occipital crest and are retracted inferiorly and laterally in one big layer with the skin. The occipital bone, the posterior arches of atlas (PAA), and the spinous process and laminae of C2 are subperiosteally exposed just like in the standard midline approach. The exposure of the PAA is then extended laterally starting by the inferior edge, next by the superior edge which in fact is the posterior limit of the VA groove. This groove extends from the transverse foramen (TF) to a step at the end of the groove where the height of

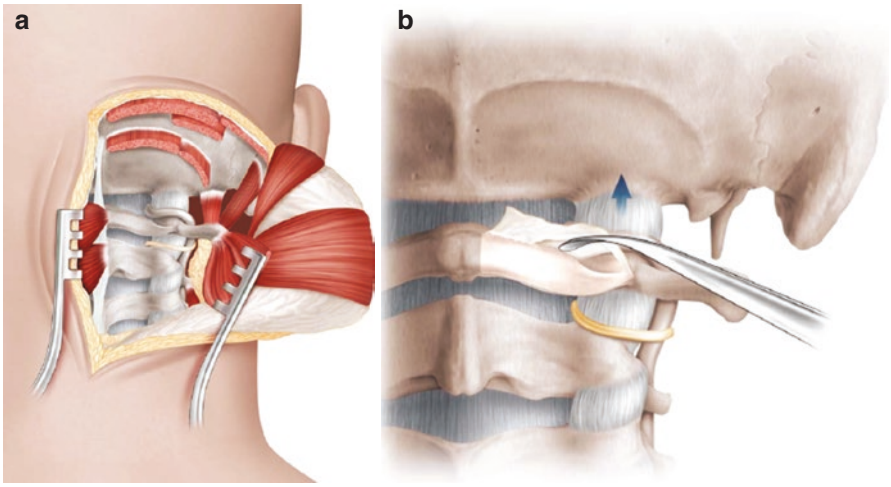

Fig. 28.1 The posterolateral approach. (**a**) Patient position, skin incision, and approach to the vertebral artery. (**b**) Subperiosteal dissection. (*From Pathology and Surgery around the Vertebral Artery. George B, Bruneau M, Spetzler RF (eds), Springer 2011)*

the PAA increases markedly (Fig. 28.1b). The subperiosteal exposure is a crucial point as it preserves the periosteal sheath surrounding the VA and its venous plexus. Therefore no troublesome bleeding is to be expected; however, some venous connections may exist between the VA venous plexus and the posterior condylar vein or the C1-C2 intervertebral plexus around the C2 nerve root. These connections can be easily coagulated and if necessary, the posterior condylar vein is controlled by Surgicel® and bone wax.

The posterolateral approach provides an easy and safe access and control to the VA segment above C1 from the transverse foramen to the FM dura. However, the vertical segment between the C2 and C1 TF is more difficult to reach in most cases. In fact, the posterolateral approach is essentially designed for the exposure of the VA horizontal segment above C1.

28.2.2 Anterolateral Approach

28.2.2.1 Exposure of the Two Vertical and Horizontal VA Segments

The anterolateral approach (Fig. 28.2a) at the CVJ level is basically similar to the one used lower in the neck to expose the VA in its V2 segment; it opens the field between the internal jugular vein (IJV) medially and the sterno-mastoid muscle (SM) laterally.

The patient is in the supine position with the head slightly extended, tilted down, and rotated toward the opposite side; in fact as C1 is rotating over C2 during head rotation the transverse process (TP) of atlas is projected anteriorly and the anterior arch is brought away.

The skin incision follows the medial edge of the SM in its superior part up to the tip of the mastoid process (MP), then curved along the superior occipital crest more or less toward the occipital protuberance following the size and shape of the neck. The posterior muscles are separated from the occipital bone and the MP including the tendon of the SM. They are then progressively retracted inferiorly and laterally. The IJV is next controlled in the inferior part of the field and progressively up to the skull base, moving up toward the MP and the digastric muscle. Between the IJV medially and the SM laterally, the depth of the field is filled by a fatty layer in which runs the accessory nerve (CN XI). This nerve should be identified and dissected free out of this fat layer that is then rolled around the nerve so as to retract the nerve inferiorly and medially. At this time of the approach, the field between the SM laterally, the IJV medially, and the digastric muscle superiorly is widely opened. About 15 mm below the tip of the MP, the tip of the TP of atlas can be palpated; it is connected with the occipital bone and C2 by several little muscles (levator scapulae, oblique and rectus muscles) which are now detached and retracted progressively giving view to the two VA segments: the vertical one between C2 and C1 and the horizontal segment in the groove of the PAA. This exposure must be achieved slowly so as to preserve the periosteal sheath of the VA and hence to avoid any troublesome bleeding. There is no landmark along the muscles resection except the anterior branch of the second cervical nerve root, which crosses the inferior part

of the C1-C2 segment. In between the two VA segments and parallel to them is the PAA. As in the posterolateral approach, the PAA must be exposed subperiosteally, first on its posterior aspect then on its superior one, e.g., on the VA groove. The VA may be followed all along the VA groove until the step at the end of this groove is reached. From this point, the VA runs obliquely and superiorly toward the FM dura. There is often a muscular branch originating at the corner between the horizontal and oblique VA segments.

Again the main trick in this exposure is to work out of the periosteal sheath encircling the VA and the venous plexus.

28.2.2.2 Opening of the Transverse Foramen of Atlas and VA Transposition

Whenever the transverse foramen (TF) of atlas needs to be opened and furthermore when it is useful to transpose the VA out of this foramen, the preservation of the

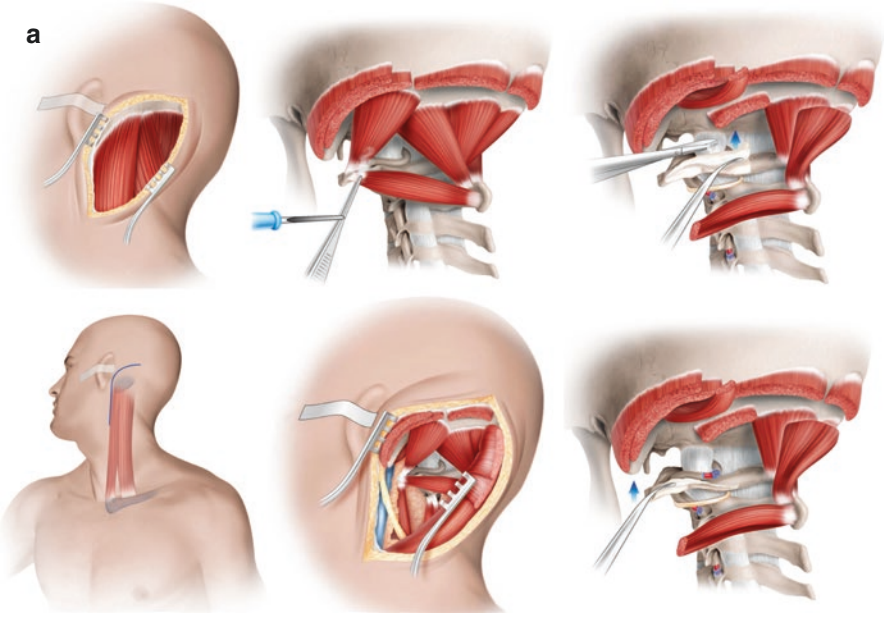

Fig. 28.2 (**a**) The anterolateral approach. A. Patient position and skin incision. B. Approach to the vertebral artery: superficial muscles exposure. C. Approach to the vertebral artery: deep muscles exposure. D. Section of the muscles inserting on the C1 transverse process. (**b**) Vertebral artery exposure and transposition. A. Subperiosteal dissection along the C1 posterior arch. B. Exposure of the VA V3 segment above C1. C. Subperiosteal dissection inside the C1 transverse foramen. D. Opening of the C1 transverse foramen by resection of the posterior branch of the C1 transverse process. E. Section of the ligament at the upper aspect of the vertebral artery, covering the occipital condyle. F. After unroofing of the vertebral artery at the level of the transverse foramen, the artery is transposed. (*From Pathology and Surgery around the Vertebral Artery. George B, Bruneau M, Spetzler RF (eds), Springer 2011*)

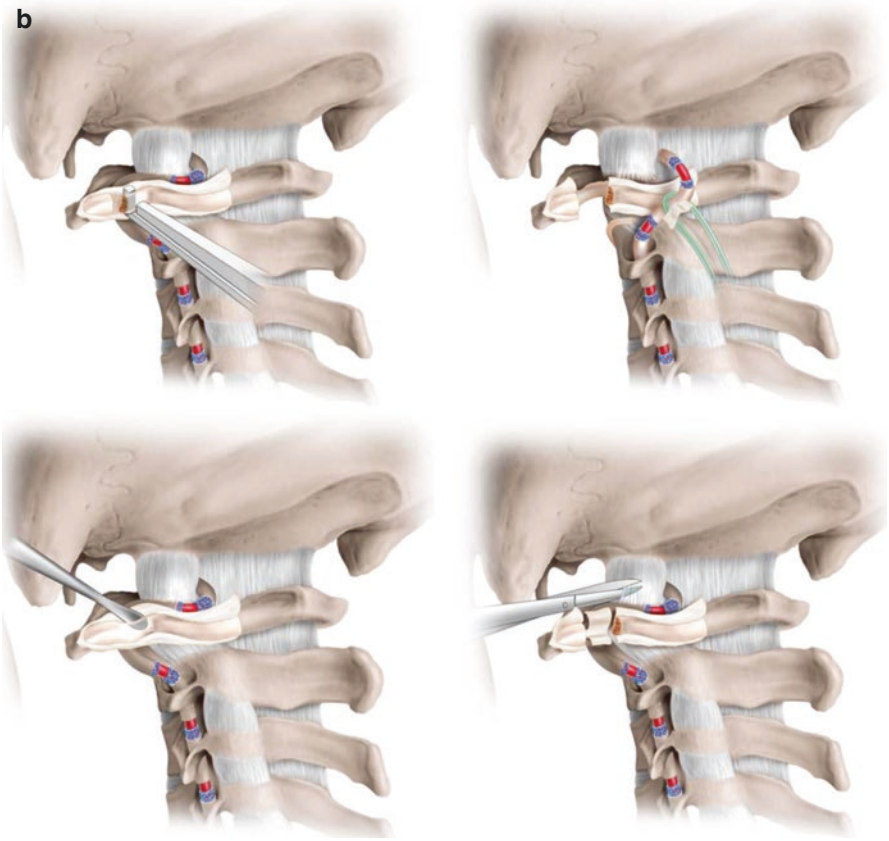

Fig. 28.2 (continued)

periosteal sheath is even more crucial (Fig. 28.2b). To achieve the opening of the C1 TF, the periosteum at the entrance and the exit of the TF must be elevated with a smooth spatula; then the heel of a Kerrison Rongeur is pushed in between the bone and the periosteum inside the TF to bite the bone covering the VA from both sides of the TF. To clear the field, the tip of the TP of atlas may be resected, as it is generally a huge piece of bone.

To transpose the VA out of the TF, the VA periosteal sheath must be split from the bone all around the VA inside the TF. Before pulling out the VA, the bone in the concavity of the loop formed by the two VA segments must be resected as much as possible. In fact, the VA may be torn during this maneuver if the tip of the PAA is not properly removed.

28.2.3 Extension Upstream and Downstream

The VA can be followed upstream as low in the neck as necessary using the anterolateral approach. For this, the skin incision is extended along the medial edge of the

SM. Then the field between the SM and the IJV is opened on as many levels as necessary.

The course of the VA between C2 and C3 is complex with a first corner at the level of the C2 TP and a second one at the base of the C2 vertebral body. After the lower end of the vertical segment between C1 and C2, the VA runs horizontally toward the C2 vertebral body and after the second corner vertically down along the transversary segment from C3 to C6. The work at the level of each TP is similar to the one done at the C1 level. The TP must be subperiosteally exposed including the inside of the TF if they need to be unroofed.

To follow the VA upstream on its V4 intradural segment, the occipital bone has to be opened; the upper the VA must be exposed, the more lateral this opening is extended toward the MP and the jugular tubercle.

28.3 Applications of the VA Exposure

28.3.1 VA Revascularization

The C1-C2 vertical segment and much more rarely the horizontal segment are the site of choice for the distal implantation of a saphenous vein graft bypassing the VA with the external, internal, or common carotid, or the subclavian artery. This bypass indication was pretty common 30 years ago to revascularize the vertebro-basilar system in case of multiple cervical vessels stenosis or occlusion. It was more rarely used to exclude cervical VA aneurysm and arterio-venous malformations by occluding the VA below the distal implantation of the bypass followed by embolization. However, all these indications have almost completely disappeared with the extensive development of endovascular techniques. It remains few indications in selected cases of tumor encasing a dominant VA when complete removal is contemplated and vessel preservation is not possible (Fig. 28.3). The VA must be completely exposed and controlled inside the periosteal sheath which hence needs to be opened. Obviously the venous plexus has to be controlled by bipolar coagulation. Most of the time the space between the C1 and C2 TF is quite sufficient to apply clips at both ends of this segment and to permit to suture the vein graft in between them. However if necessary the space may be enlarged by the opening of the C1 TF.

28.3.2 Extrinsic Compression of the VA; Bow Hunter Syndrome

This syndrome is rare but must be clearly identified since an appropriate and very efficient treatment can be proposed. It corresponds to an intermittent and severe compression of the VA in its V3 segment during a particular movement of the head and neck; this movement must always be the same and must induce a severe stenosis or an occlusion as demonstrated on any exam. Today angiography is no more necessary; Doppler ultrasound study and angio-CT are quite demonstrative and less invasive. The compression may be due to a bony or tendinous anomaly. Bony

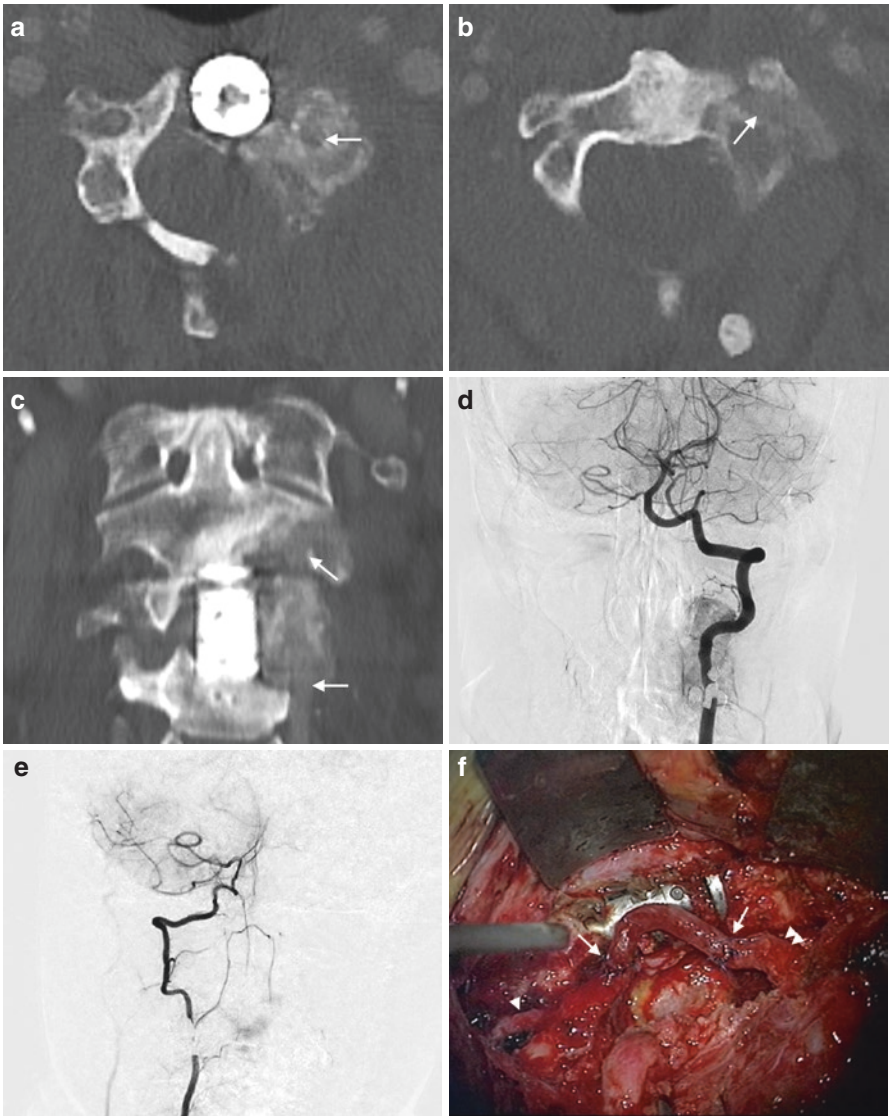

Fig. 28.3 Vertebral artery reconstruction by a C2-C4 bypass in a case of recurrent osteoblastoma. (**a**) This woman was already operated on twice in another institution with partial resection of the tumor and C2-C4 reconstruction with a distractible cage. The tumor remnant was growing. The tumor completely encases the left vertebral artery (arrow). (**b**) The tumor extends up to the base of C2 in close relation with the area where the vertebral artery performs an acute lateral bend (arrow). (**c**) Coronal view showing the relations between the tumor and the vertebral artery (arrows). (**d**, **e**) The left vertebral artery is clearly dominant and vascularizes the tumor. The left vertebral artery can not be sacrificed. (**f**) Intraoperative view after complete resection and reconstruction of the vertebral artery with a saphenous graft bypass. Proximal (arrowhead) and distal vertebral artery control (double arrowhead) were gained early in the procedure; temporary clips were placed at this level during the bypass. (**g**–**j**) Postoperative angio-CT controls confirming complete tumor resection and bypass patency (arrows). (*With permission of Erasme Hospital, ULB*)

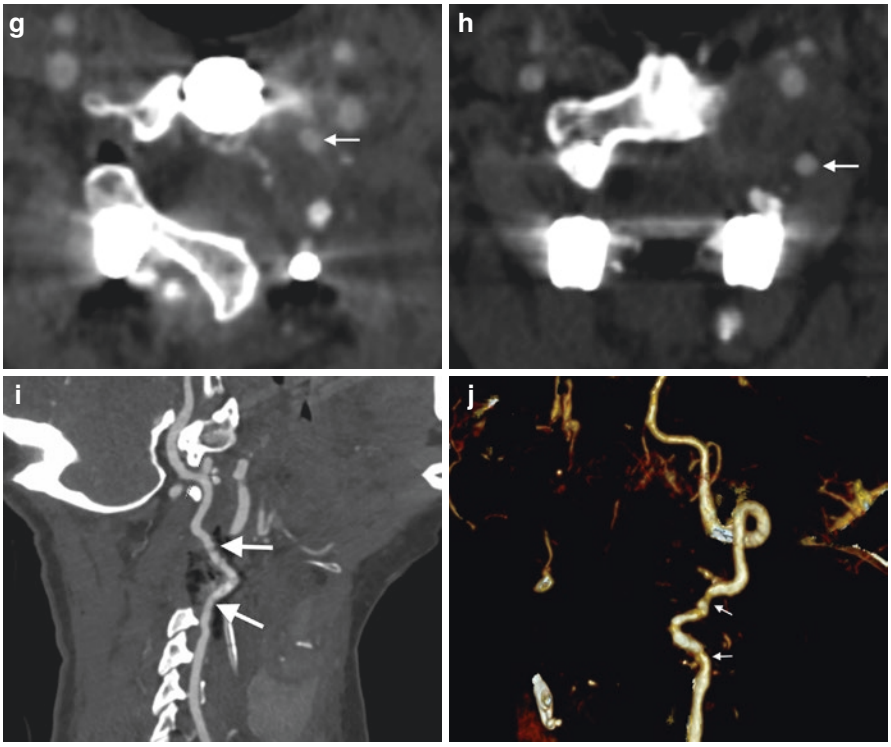

Fig. 28.3 (continued)

malformations are quite common at the CVJ including a supplementary piece of bone on the condyle or the lateral mass of atlas or a Klippel–Feil malformation with fusion between C1 and C2; it may be also tendon thickening either on the vertical (C1-C2) or the horizontal (above C1) segment. In our experience, the anterior branch of the C2 root crossing the anterior aspect of the VA C1-C2 segment may be part of the compression and had always to be cut.

The anterolateral approach is generally used with resection of the compressing element and very often the opening of the two TF (C1 and C2) and the cut of the C2 root. Some authors have also proposed to suppress the offending movement by an arthrodesis but this strategy can have a significant impact on head rotation and the quality of live [5, 7, 21].

28.3.3 FM Tumors

FM tumors and especially, by much the most frequent ones, meningiomas are best treated using the posterolateral approach. FM meningiomas are classified based on their compartment of development, their dural insertion, and their relation to the vertebral artery (Fig. 28.4). The bone opening is more or less extended following the

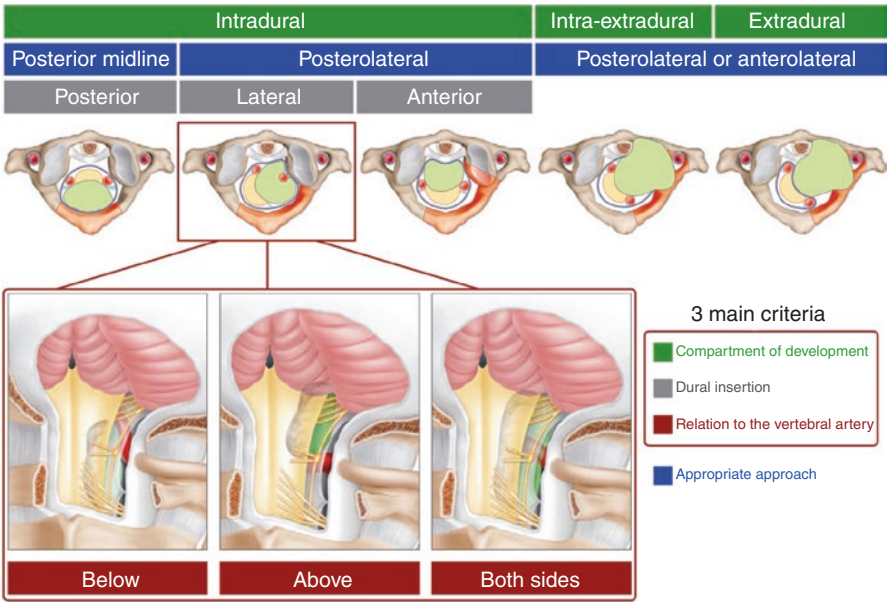

Fig. 28.4 Classification system of foramen magnum meningiomas. This classification system allows for determining preoperatively the adequate surgical strategy by determining the appropriate surgical approach and anticipating the modified position of vital neurovascular structures. FMMs are first classified by their compartment of development: purely intradural tumors, intra-extra-dural tumors, and purely extradural lesions. Intradural meningiomas are then subdivided according to their base of insertion and their relation with the VA, determining, respectively, the tumor position in the horizontal and vertical plane. According to their base of insertion, FMMs can be classified into anterior if its base of insertion is observed on both sides of the midline, lateral if it takes its origin between the midline and the dentate ligament, and posterior if found behind this ligament. According to their relation with the vertebral artery, FMMs are able to develop below, above, or on both sides of the VA. When located below the VA, the lower cranial nerves are always displaced cranially and posteriorly. If the meningioma grows above or on both sides of the VA, the position of the lower cranial nerves cannot be anticipated. (*From Pathology and Surgery around the Vertebral Artery. George B, Bruneau M, Spetzler RF (eds), Springer 2011*)

tumor location; anterior ones attached on both sides of the anterior midline need as lateral an extension as possible while lateral ones attached between the anterior midline and the denticulate ligament need a limited lateral opening. In fact with the posterolateral approach as described above (Sect. 28.2.1), it is never useful to drill far laterally either the occipital condyle or the lateral mass of atlas.

In case of involvement of the dura at the level of the VA penetration, it is safer to cut the dura at some distance around the VA so as to leave a cuff of dura because of the interconnection between the dura and the VA adventitia (see chapter anatomy).

The posterolateral approach is essentially designed for any intradural FM tumors (Fig. 28.5) but may be also applied on some extradural pathologies located inside the bone limits of the CVJ.

28.3.4 CVJ Tumors

Tumors involving the bone structures of the CVJ or developed in contact with them are best treated using the anterolateral approach (Figs. 28.6 and 28.7). The first basic principle is to perfectly delineate on the image workup the tumor and the useful extent of resection to drill no more than the necessary bone. Based on this principle, in the vast majority of cases, the bone drilling must not create a CVJ instability; the instability should essentially be due to the bone destruction by the tumor and almost

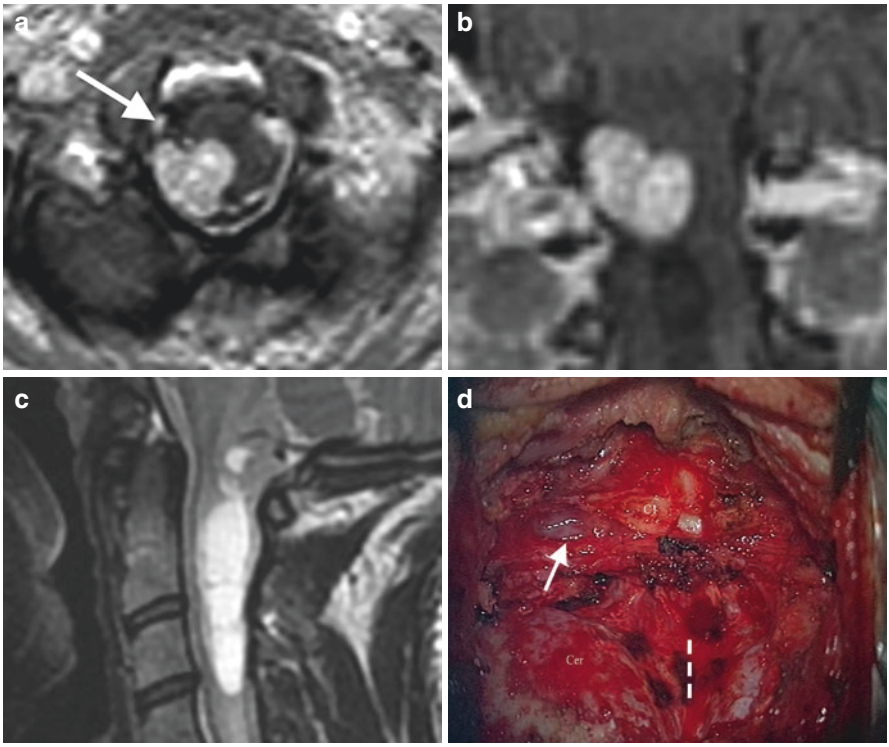

Fig. 28.5 Bulbomedullar hemangioblastoma. (**a**) The tumor is laterally located, close to the intradural segment (V4) of the vertebral artery. (**b**) Coronal view at the foramen magnum level. (**c**) The tumor is responsible for a syringomyelia. (**d**) View after the bilateral suboccipital craniotomy, more extended on the right side, exposing the cerebellar dura matter (Cer). The midline is showed with dotted line. The horizontal portion of the right vertebral artery V3 segment is visible above the C1 posterior arch (arrow). (**e**) Subperiosteal exposure of the horizontal portion of the vertebral artery V3 segment above the C1 posterior arch through a postero-lateral approach. (**f**) The control of the V3 segment allows to resect the C1 posterior arch laterally up to the C1 lateral wall and then to retract the dura matter more laterally. By doing this, the tumor can be exposed safely without any risk of tumor disruption to achieve a complete en-bloc resection and avoid profuse bleedings. The intradural segment of the vertebral artery (arrow) and the lower cranial nerves are controlled at the beginning of the procedure. (**g**) View at the completion of the complete resection. Neurological examination remained unchanged. (*With permission of Erasme Hospital, ULB*)

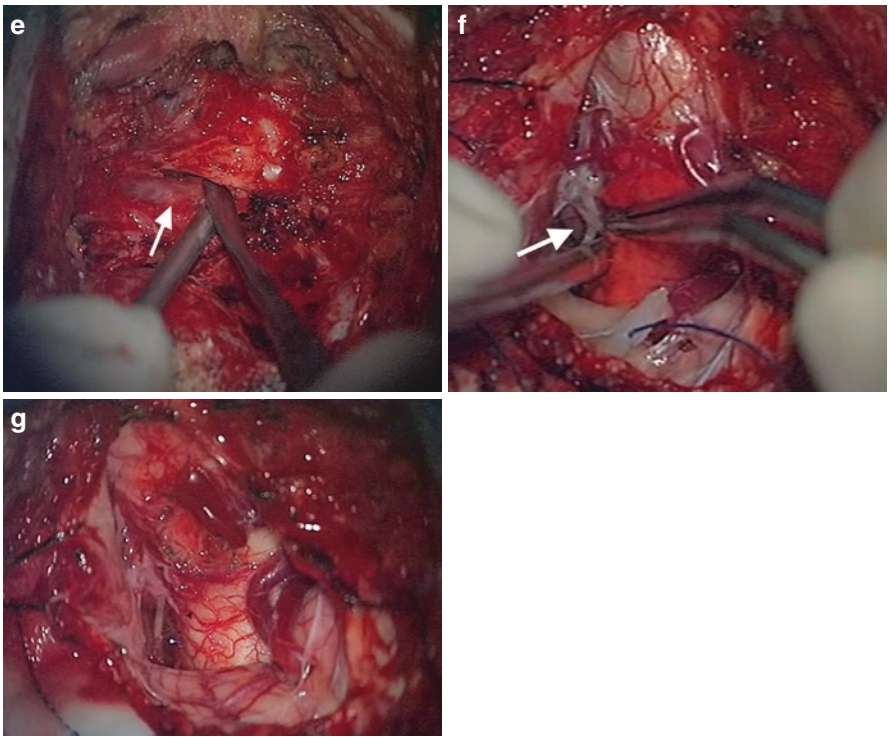

Fig. 28.5 (continued)

never to the surgical drilling. Following these points, an occipito-cervical fusion may have to be considered preoperatively and rarely postoperatively. In very particular cases, a bone graft, occasionally screwed, can be placed as a fixation.

The second basic principle is, before all, to control the VA on both sides of the tumor. Then if the VA is encased by the tumor, its size must be appreciated and a balloon occlusion test asked if a dominant VA has to be sacrificed or is at risk during the surgery.

28.3.5 JF Tumors

JF tumors include essentially paragangliomas (glomus tumors), neurinomas, and meningiomas [3, 22].

Especially for glomus tumors, the VA is one of the vasculo-nervous elements that need to be controlled in a first step before considering the tumor resection. Moreover, its control is necessary to gain a postero-inferior access to the JF without the need for any petrous bone drilling. This technique called the juxtacondylar approach is an extension of the anterolateral approach. The first step is the VA exposure, followed by the

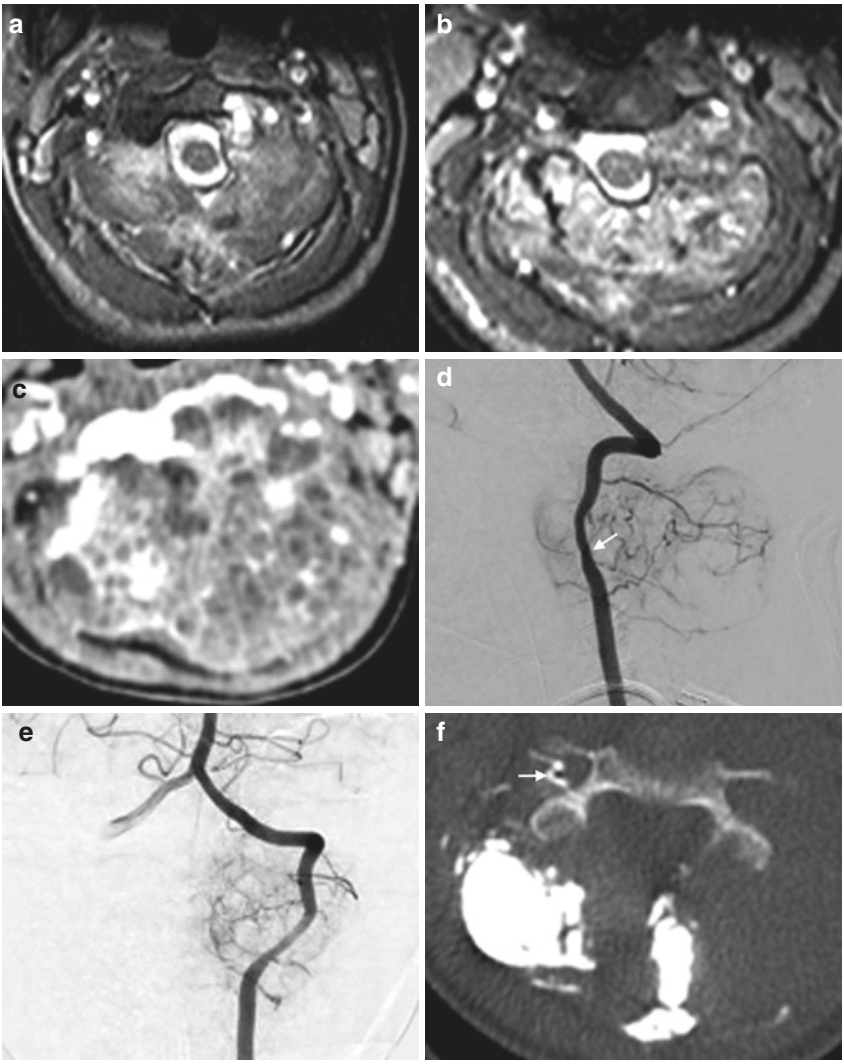

Fig. 28.6 Aneurysmal bone cyst quickly growing in a 6-year-old girl. (**a**, **b**) Preoperative MRI showing the tumor involving the posterior elements and the C2 vertebral body and C2-C3 intervertebral foramen on the left side. (**c**) Six weeks later, the tumor has grown significantly and compresses the spinal cord. Despite the compression, the neurological status remains normal. (**d**, **e**) The left vertebral artery vascularizes the tumor through several branches. The artery was compressed by the tumor (arrow). (**f**) The tumor was preoperatively embolized through direct transcutaneous punctures. The procedure was interrupted when observing some embolization material in the right vertebral artery (arrow). (**g**) The patient was operated on through a left lateral approach and then a posterior approach. The postoperative angio-CT shows the patent left vertebral artery (white arrow), the bone graft placed inside the C2 dens (black arrow), the bone graft between the C1 posterior arch and the C3 lamina on the right side (arrowhead). (**h**) After 6 months, the C2 bone graft was completely integrated (arrowheads). (**i**) View at the level of C2 showing the bone graft and reconstruction of the C2 lamina using bone chips. (**j**) Postoperative stabilization was achieved with C1 lateral mass screws and C3-C4 hooks due to the small size of the facets in this child. (**k**) MRI at 6 months confirms the complete resection. (*With permission of Erasme Hospital, ULB*)

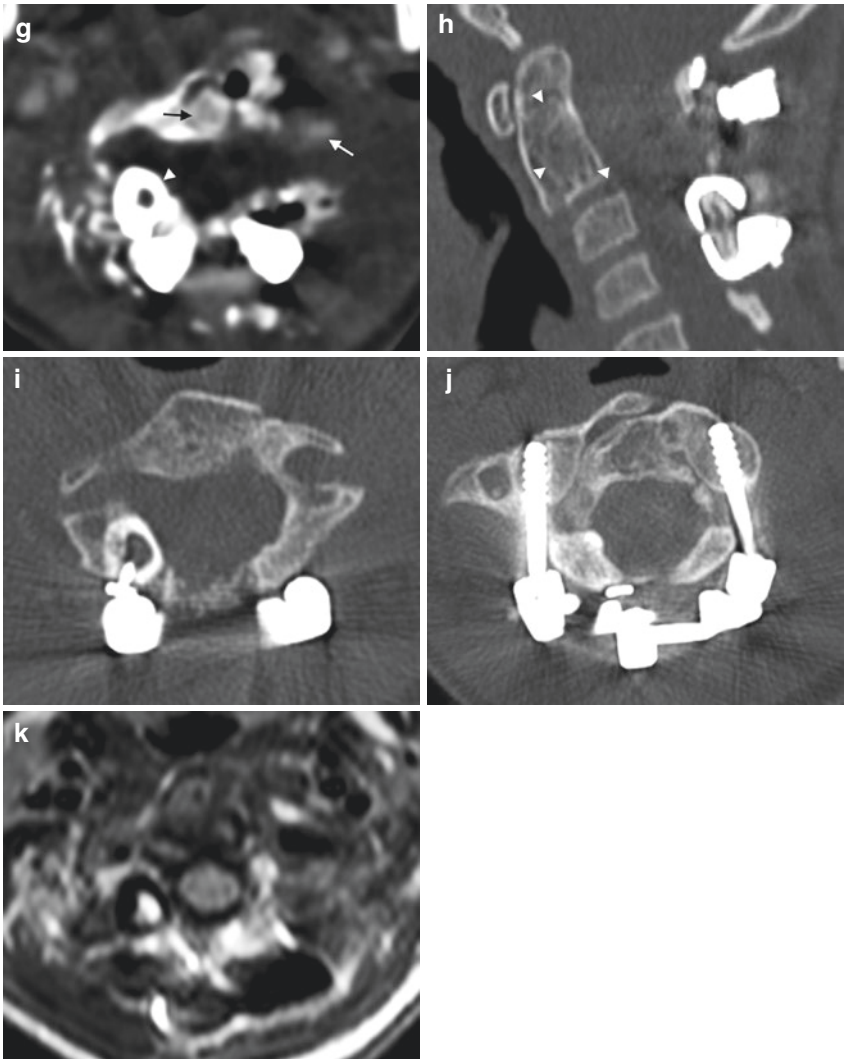

Fig. 28.6 (continued)

control of the vasculo-nervous cervical elements as needed: the internal and external carotid arteries; the IX, X, XI, and XII cranial nerves; and the sympathetic chain. Then a retrosigmoid opening is realized including a mastoidectomy exposing the last centimeters of the sigmoid sinus (SS). At this point it remain some bone covering the JF between the upper part of the IJV and the end of the SS. Unroofing the JF is rather easy in most cases since the JF is much enlarged by the tumor, the bone cover is thin, and the SS is generally occluded. Therefore this approach is quite sufficient for any tumor developed inside the bony limits of the JF. This is generally the case of neurinomas. Conversely in cases of tumors overtaking these bony limits and extending into the petrous bone, the bone drilling must follow these extensions but can be limited.

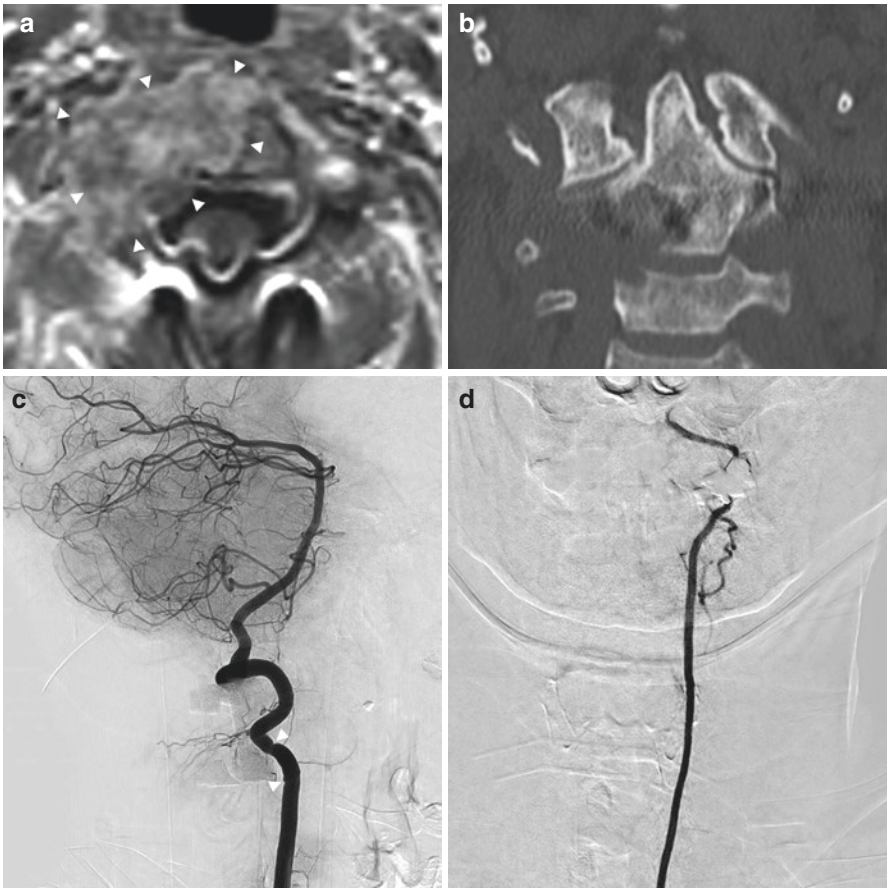

Fig. 28.7 The patient suffered from a right-sided C2 chordoma. The patient has already had a biopsy and a posterior fixation elsewhere. (**a**) The tumor (arrowheads) destructed the C2 vertebral body and the C2-C3 facet joint, and extended to the surrounding soft tissues, including the C2-C3 intervertebral foramen. (**b**) Coronal view showing also the extension to the uncus of C3. (**c**) The right vertebral artery was dominant. Note that the artery irregular to the compression by the tumor (arrowheads). (**d**) The contralateral vertebral artery was hypoplastic. (**e**) The tumor has been resected through a right-sided lateral approach. Note the exposure of the spinal accessory nerve (black arrow). The vertebral artery was first controlled at the level of the C1 transverse foramen (arrow) and then at the C3 level. (**f**) The vertebral artery is visible at the C2 level, showed by the forceps. (**g**) View after tumor resection extended up to normal bone. The vertebral artery is visible inside the periosteal sheath (arrow). (**h**, **i**) MRI confirmed the complete resection of the tumor and showed the right vertebral artery (arrow) after its dissection. (**j**) Bone stabilization was achieved using a distractible cage filling the bone defect and a 2-screw lateral plate. (*With permission of Erasme Hospital, ULB*)

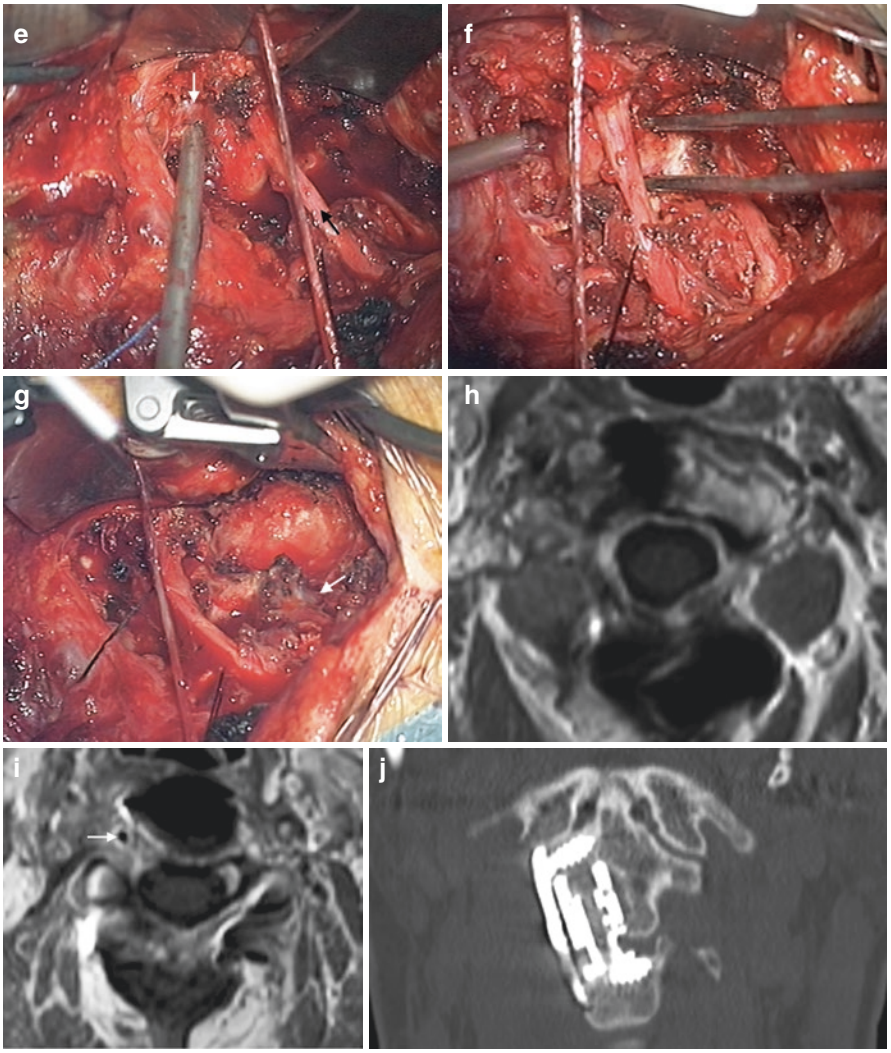

Fig. 28.7 (continued)

28.4 Risks and Hazards of the VA Exposure

The VA exposure in the neck from its origin to the FM dura penetration is a well-defined technique applied in our experience in more than 1700 cases including more than 400 at the CVJ (V3 level). Mortality and morbidity related to the VA exposure is very limited. There is no mortality, and morbidity is limited to some damages to

the accessory nerve in three cases with painful stiffness of the SM resolving in 2 or 3 months. It can be explained by a too strong retraction of the SM. In our experience, no tear of the VA occurred.

28.5 Conclusions

The VA in its V3 segment at the CVJ level can be exposed and controlled using two well-defined techniques: the posterolateral approach essentially useful for intradural FM tumors and the anterolateral approach for VA revascularization, release of extrinsic intermittent compression, and resection of CVJ and JF tumors. In our experience, a complete resection can be achieved in most cases with limited morbidity and mortality.

The VA exposure is a well-defined technique, which can be easily applied after some training. The main trick is to preserve the periosteal sheath surrounding the VA and its venous plexus. Overall the VA control permits to extend the access around the CVJ without inducing in most cases a CVJ instability, avoiding unnecessary petrous bone drilling, and generally permitting a safe and radical tumoral resection. Moreover, the VA can be followed upstream in the lower neck and downstream inside the posterior fossa.

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