5 Anterior Subaxial Cervical Approach

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Part I: General Considerations of the Anterior Cervical Approach

History of the Anterior Cervical Exposure

Detailed descriptions of anterior exposure of the subaxial cervical spine for treatment of ventral spinal pathology first appeared with descriptions written by Smith-Robinson [1], followed closely by Cloward [2] in the mid-twentieth century. Improvements in the comprehension of anatomy and biomechanical principles, advancements in the design of self-retaining retractor systems and intraoperative lighting, and widespread microscope availability have made the anterior approach to the cervical spine a common and safe technique.

General Considerations of the Anterior Cervical Approach Versus Posterior Approach

Although posterior decompressive laminectomy has been a mainstay of treatment, use of anterior (also referred to as "ventral") approaches for direct decompression in the setting of subaxial cervical spine tumors has become increasingly popular as techniques for spine stabilization and reconstruction have evolved.

Posterior laminectomy with or without instrumented fusion may potentially afford the opportunity for decreased operative time while simultaneously addressing compressive symptoms from tumors lying either dorsal or ventral to the spinal cord. It additionally provides a means for decompressing nerve roots at the level of the foramen, and complete access to tumors lying dorsal to the thecal sac. However, posterior-only approaches, even in the face of instrumentation, may carry a risk of progressive kyphotic deformity [3, 4], and furthermore may be ill-suited for obtaining oncologic control of ventrally-located tumors.

Anterior cervical approaches provide a route for direct decompression of neural elements as well as resection of ventral subaxial tumors, and allow for immediate reconstruction and stabilization of the spinal column. They offer the opportunity for tissue diagnosis, oncologic control, and carry lower risks of infection, lengthy hospital course, and pseudoarthrosis than the posterior approach alone. Patients with kyphosis, particularly those with fixed kyphotic deformities, may experience better correction of alignment through inclusion of an anterior or combined approach [5]. Anterior-alone approaches do, however, have limited utility in addressing tumors dorsal to the spinal cord, may have a longer operative time, and carry risks of dysphagia and injury to the recurrent laryngeal nerve [6, 7], carotid sheath, and mediastinal

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structures. Anterior approaches requiring partial or complete corpectomies carry additional risk of injury to the vertebral artery as it passes through the transverse foramina, particularly if the tumor distorts the anatomy.

Pertinent Neural Anatomy

Symptoms from subaxial cervical spine tumors include intractable pain, which may be mechanical or radicular in nature, as well as myelopathic symptoms from compression of the spinal cord. The median cervical spinal cord diameter is 10 mm, and the median cervical canal diameter is 17 mm; symptoms may be more likely to develop when canal diameter is reduced to 10 mm or less [8, 9].

Pathology

The majority of tumors found in the subaxial cervical spine include primary mesenchymal neoplasms, meningothelial tumors, nerve sheath tumors, hematopoietic lesions, and metastases.

The cervical spine is also subject to spondylotic change, which when superimposed upon the neoplastic disease, must be taken into consideration when formulating a management algorithm. Changes such as degenerative disc disease, hypertrophy or ossification of the posterior longitudinal ligament (OPLL), facet arthropathy, and osteophyte formation may occur in isolation or as part of a syndromic constellation (diffuse idiopathic skeletal hyperostosis, ankylosing spondylitis, etc.). Reducible, non-ankylosed deformity may be corrected utilizing lordotic grafts, positioning techniques including extension and traction, convergent Caspar pin placement, and instrumentation. Non-reducible deformity requires more surgical techniques such as osteotomies, and may necessitate combined anterior/posterior approaches for adequate reduction of listhesis and correction of kyphosis [5]. Plans to correct alignment in the setting of oncologic burden should weigh the risk of morbidity associated with extensive deformity correction with the patient's oncologic prognosis, degree of systemic disease control, and medical comorbidity.

Anterior Cervical Exposure and Local Anatomy

Some literature supports a left-sided approach to the spine, as the recurrent laryngeal nerve (RLN) lies protected between the trachea and esophagus during exposure, compared to the relatively more vulnerable course of the right recurrent laryngeal nerve [6]. Subsequent studies have shown that surgeon handedness and preference, revision surgery, and tumor configuration may dictate a right-sided approach, which can be performed with no increased rate of transient of permanent dysphonia [7]. In patients with prior anterior cervical spine exposures or potential lower cranial nerve involvement by the neoplastic process, evaluation by otolaryngology is recommended to assess vocal cord function. In the presence of preexisting injury, surgical approach should be planned for the ipsilateral side to avoid a devastating bilateral RLN injury. Further, the anatomic location of the tumors should be evaluated and considered since its involvement with the neural or vascular structures may alter approach strategies. The surgeon should feel comfortable with both approaches (right versus left) such that they choose the approach with the least potential morbidity.

A horizontal incision within a skin crease is commonly used for short segment and degenerative fusions. However, when performing multilevel procedures or when approaching a ventral spine tumor, a wide exposure is often beneficial. This can be accomplished with a carotid-type incision to provide adequate exposure while minimizing retraction on soft tissue structures.

The operative exposure traverses a predictable anatomic course. After opening the initial skin incision, the platysma is divided either transversely or in parallel with the direction of its fibers. With adequate dissection of the pre- and postplatysmal planes, four or even five levels may be readily accessed through a single transverse incision. Passing medially to the SCM, the omohyoid is identified and circumferentially dissected; it may be divided without significant consequence, but often it is easily simply retracted out of the surgical corridor. An avascular plane is developed medial to the carotid sheath and lateral to the esophagus/trachea. The spine is palpated and the anatomic levels are identified and confirmed with radiography. The longus colli muscles, an important landmark identifying the midline, are reflected laterally with subperiosteal dissection and may serve as an anchor point for the self-retaining retractor system. Discectomy with or without corpectomy and tumor resection may be carried out. Spinal tumors typically do not invade the disc spaces, which should be preserved initially such that discectomies can be done above and below the tumor, leaving the en bloc removal of the lesion as the final portion of the procedure. If the tumor is vascular in nature, consideration of preoperative embolization is often beneficial. Once the surgeon enters the tumor, bleeding will decrease significantly once the lesion is circumferentially dissected and vascular supply is removed. It is our practice to remove the posterior longitudinal ligament, as we have found that it is often infiltrated with tumor cells.

Reconstruction and Stabilization: Options and Challenges

Unfortunately, with oncologic patients there is always the concern for pseudoarthrosis, particularly those with a history of tobacco or chronic steroid use, or patients who will require aggressive postoperative chemotherapy or radiation. In these patients, autologous bone such as iliac crest or even vascularized free-flap grafts should be strongly considered as the graft material. The patient should be positioned, prepped, and draped in a way that facilitates graft harvesting. The use of vascularized free grafts from long bones requires coordination between the surgical teams and should be planned well in advance. Additional alternatives to autograft include cadaveric tricortical graft as well as synthetic materials (i.e., PEEK, titanium, etc.). These minimize the donor site morbidity and allow for ease of sizing and choice of lordosis but may have an increased risk of nonunion. Various plating systems exist, and choice is dependent on surgeon preference, as well as institutional vendor availability. Placement of screws should be divergent in the sagittal plane and convergent in the axial plane to minimize the risk of pull-out. If there is concern for the bone purchase and/or construct stability, posterior augmentation should be considered (Figs. 5.1 and 5.2).

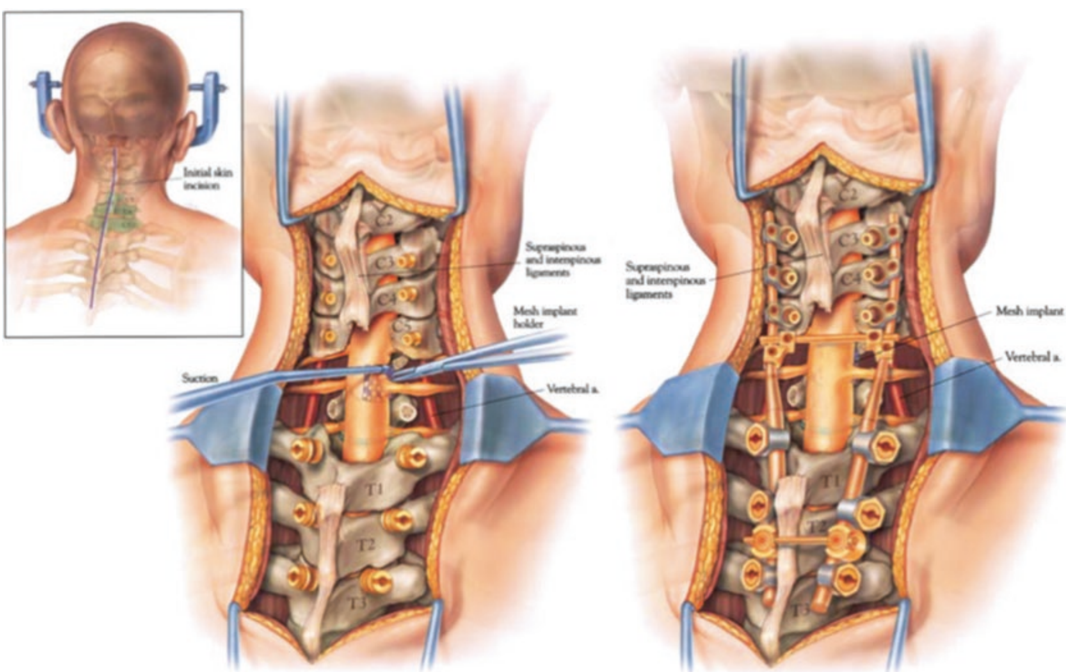

Fig. 5.1 Posterior stabilization for cervical spondylectomy to achieve oncologic margins for cervical osteogenic sarcoma. (Reprinted with permission from Cohen et al. [10])

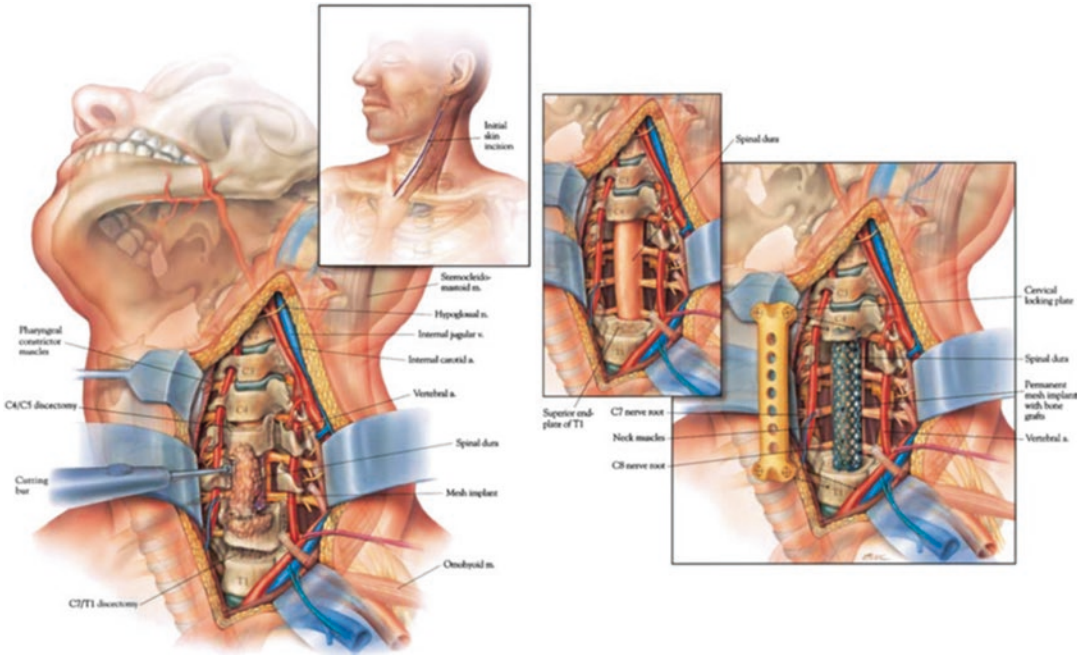

Fig. 5.2 Anterior subaxial cervical spondylectomy for osteogenic sarcoma. (Reprinted with permission from Cohen et al. [10])

Complications and Avoidance

The anterior cervical approach carries a risk of injury to the RLN, esophagus, thyroid, trachea, as well as the carotid or vertebral arteries, the vagus nerve, and the sympathetic chain. Knowledge of the relevant operative anatomy is paramount in avoiding such injuries, and the ability to recognize aberrant anatomy on preoperative imaging, or early in the operative exposure, will minimize intraoperative damage to these structures. Normal anatomical landmarks may be obscured by previous surgery or previous radiation, thus enlistment of a head-and-neck team for exposure should be considered. Although anterior cervical approaches generally carry a low risk of durotomy, in patients with underlying tumors, there may be calcification of the PLL or invasion/erosion of the dura, which make dural tear inevitable. In the event of a CSF leak, direct visualization and primary repair is recommended, although dural substitute or fibrin sealants, as well as lumbar subarachnoid drainage postoperatively, may be considered. Direct injury to the cord and nerve roots remains a risk and may be increased by tumor configuration, consistency, and invasion of neural structures. Long-term complications include the risk of pseudoarthrosis, graft displacement or migration, and instrumentation failure.

Part II: Oncologic Considerations of Anterior Cervical Surgery

Primary Versus Metastatic Lesions

Tumors of a wide variety of histologies may affect the subaxial cervical spine [11–18]. Tumor histology is one of the primary considerations that dictate treatment in a specific individual and can be broadly organized into two categories: primary spinal tumors and metastases. Both primary and metastatic lesions exhibit varying degrees of radiosensitivity. With the advent of image-guided radiation therapy techniques such as stereotactic radiosurgery (SRS), it is now possible to treat tumors that were traditionally considered radioresistant to conventional external beam radiotherapy [19, 20], as image-guided techniques have the capability to limit dosage received by the spinal cord and other critical nearby structures [21]. In light of this, nonsurgical options may have similar outcome in some instances of spinal metastasis [17, 18, 20, 22]. Conversely, many authors would advocate neurosurgical consultation for all primary tumors of the spine, as en bloc resection may be curative [19]. Therefore, surgeons should have an understanding of the histology, as it may alter the surgical approach and treatment. In isolated or unusual lesions, a biopsy should be considered in order to establish the diagnosis. For example, a cure can be effected in the case of a primary tumor treated with an en bloc resection, whereas an intra-lesional approach most likely will lead to recurrence. The potential morbidities of the more aggressive en bloc resection must be discussed with the patient so as to understand their goals and aims in terms of quality of life.

Primary Spinal Tumors

Primary spinal tumors are extradural lesions that are significantly less common than their metastatic counterparts. Primary lesions span the full spectrum of histological aggression. Furthermore, ultrastructurally benign lesions such as chordoma typically behave in a more locally destructive manner than their histology might belie. Primary neoplasms are most typically mesenchymal in origin and include benign lesions (chondroma, osteoma, hemangioma) as well as malignant tumors (sarcomas).

Primary tumors are often considered separately, as complete resection has the potential to be curative. With the ever-expanding role that SRS has been shown to occupy with metastatic disease, there is more leeway with the extent of resection that is necessary for metastatic lesions, and in many instances, a smaller and potentially less morbid procedure is indicated.

Metastatic Lesions

The great majority of extradural spinal cord tumors represent metastases. Among the most common primary spine tumors are breast, prostate, gastrointestinal, and lung cancers, as well as lymphoma and melanoma [19]. Metastases by definition are histologically aggressive; however, some lesions behave more indolently than others, and susceptibility to radiation therapy varies markedly. All of these attributes factor into the surgical decision-making process.

The NOMS Framework [19] is a multidisciplinary algorithm that has been developed at Memorial Sloan-Kettering Cancer Center to facilitate the decision-making process regarding metastatic disease of the spine. The algorithm assesses four aspects of the patient's clinical presentation: the patient's neurologic status ("N"), the oncologic behavior of the tumor ("O"), the mechanical stability of the spine ("M"), and the patient's systemic disease burden and degree of medical comorbidity ("S") [19].

For the assessment of the degree of spinal stability, the NOMS Framework draws on previous work done by the Spine Oncology Study Group. The Spine Oncology Study Group's Spinal Instability Neoplastic Score (SINS) is itself a tool that assigns a continuum of points based on seven of the patient's radiographic and clinical features [23]. According to the criteria set forth by the SINS algorithm, and with specific regard to the subaxial cervical spine, instability is more likely when junctional levels (occiput–C2, C7–T2) are involved as opposed to the relatively "mobile" subaxial region, if the patient experiences mechanical pain, if lesions appear lytic, if there is radiographic deformity present, if translation or subluxation is apparent on dynamic imaging, if vertebral body collapse is present, or if there is involvement of the posterior elements. These criteria are summarized in Table 5.1, which is adapted from Fisher et al. [23]. Overt instability is an indication for fixation that is independent of other features of the patient's presentation.

The neurologic assessment according to the NOMS Framework is predicated upon the degree of radiographic epidural involvement of the epidural space [19, 24]. The scale ranges from 0 to 3, with a score of 1 being further subdivided into 1a, 1b, and 1c. In general, a lower score would direct care toward radiation therapy. Radiation may still be the optimum therapy in light of more significant compression if a tumor were to be particularly radiosensitive. The scale for neurologic assessment is summarized in Figs. 5.1 and 5.2, which has been reprinted from Bilsky et al. [24].

The patient's oncological assessment is primarily concerned with the tumor's anticipated response to radiation therapy [19]. Gerszten [18] and Laufer [19] have provided excellent summarizations of the findings of multiple authors regarding the relative radiosensitivity of various metastatic malignancies to SRS. Hematologic and germinomatous malignancies are generally considered radiosensitive [18, 19], whereas other tumor histologies vary widely with regard to their sensitivity [11–17]. According to Laufer [19], who drew on earlier work from Gerszten [18], relatively radiosensitive solid tumors include breast and prostate tumors, whereas tumors that typically exhibit radioresistance include such histologies as sarcoma, melanoma, renal cell malignancy, and non-small-cell lung carcinoma.

Table 5.1 Criteria of the Spine Oncology Study Group's Spinal Instability Neoplastic Scale (SINS)[a]

Location	
Junctional (occiput–C2, C7–T2, T11–L1, L5–S1)	3
Mobile spine (C3–C6, L2–L4)	2
Semirigid (T3–T10)	1
Rigid (S2–S5)	0
Pain	
Yes	3
Occasional pain but not mechanical	1
Pain-free lesion	0
Bone lesion	
Lytic	2
Mixed (lytic/blastic)	1
Blastic	0
Radiographic spinal alignment	
Subluxation/translation present	4
De novo deformity (kyphosis/scoliosis)	2
Normal alignment	0
Vertebral body collapse	
˃50% collapse	3
˂50% collapse	2
No collapse with ˃50% body involved	1
None of the above	0
Posterolateral involvement of spinal elements	
Bilateral	3
Unilateral	1
None of the above	0
Total score	
Stable	0–6
Indeterminate	7–12
Unstable	13–18

[a]Adapted from Fisher et al. [23]

Finally, the patient's systemic disease burden and overall degree of medical comorbidity, suitability for surgery, and life expectancy must be assessed [19]. A thorough oncologic staging can have profound implications regarding the potential for prolonged palliation and therefore underscores the rationale for aggressive intervention. The major points of the NOMS Framework for the management of metastatic spinal disease are summarized in Fig. 5.3. However, tumor sensitivity and response to treatment are changing rapidly with the use of new chemotherapy agents and additional radiosurgery techniques such that surgeons need to coordinate care with the radiation oncology and medical oncology colleagues.

Diagnostic and Therapeutic Adjuncts to Surgery

Positron emission tomography ("PET scan") can be a useful adjunct to standard CT and MRI for evaluation of newly discovered spinal lesions. In

NOMS	Variable	1	2	3	4
Neurologic	No significant compression/deficit	X	X		
	Epidural compression + neurologic deficit			X	X
Oncologic	Radio-sensitive	X		X	
	Radio-resistant		X		X
Therapy		Conventional XRT	SRS	Conventional XRT	Separation surgery + SRS

Fig. 5.3 Summary of the NOMS Framework. (Adapted from Laufer et al. [19])

instances where the diagnosis is still unclear and tumor histology may influence the choice of surgical procedure, CT-guided needle biopsy can be invaluable. Considerations such as needle insertion point and trajectory must be kept in mind for locally aggressive or frankly malignant lesions, as this may risk seeding surrounding unaffected tissues, and histology may ultimately dictate that the biopsy tract itself should be resected.

Endovascular therapy is a relatively recent adjunct that has the potential to facilitate safe and complete resection in many instances. Some lesions affecting the cervical spine have the propensity to recruit a particularly robust vascular supply. Other lesions, such as metastatic renal cell carcinoma and hemangioma, are notorious for their vascular channels that may bleed profusely when dissected. Lesions of a vascular nature such as these may be embolized preoperatively in an effort to limit the bleeding that may be encountered intraoperatively.

In addition, locally aggressive lesions such as chordoma may grow to engulf or even invade the adventitia of the critical vascular structures of the neck. In these instances, a preoperative angiogram may be indicated for several reasons. Irregularities of the lumen of a critical vessel noted on angiography may indicate vessel invasion by the tumor, and based on this finding, a contingency plan may be formulated preoperatively, including ensuring that vascular clamps and blood products are readily available in the event of hemorrhage. In addition, assessment of collateral flow and even test balloon occlusion (TBO) can be performed during the preoperative evaluation of the newly diagnosed lesion, providing valuable information regarding possible downstream sequelae from vessel injury or sacrifice. Finally, endovascular techniques may facilitate vessel sacrifice peroperatively.

Goals of Surgery

The traditional goals of spinal surgery are (1) neural decompression, (2) restoration of alignment, (3) stabilization, and (4) arthrodesis. The decompression of neural elements serves ultimately to preserve existing function. In instances of neurologic deficit in the face of epidural compression, multiple studies have demonstrated that timely surgical decompression affords the best opportunity to preserve or regain ambulatory function and maintain control of bowel and bladder.

Additional concerns that are specific to spinal oncology also include obtaining a tissue diagnosis, and the possibility of a surgical cure must be entertained in appropriate situations of primary neoplasms. For this to be achieved, a complete en bloc resection with margins must be performed. In instances where en bloc resection is not possible or is ill-advised due to the potential for morbidity or mortality, a spectrum of debulking exists, which ranges from gross total resection to separation surgery only, depending on the tumor histology. For all procedures, adjuvant therapies such as radiation therapy or chemotherapy form an integral part of the patient's treatment algorithm. For metastatic disease, the goal is palliation care and maximization of the patient's quality of life.

With regard to the treatment of spinal metastases, recent data seem to indicate that the concept of "separation surgery" combined with postoperative image-guided radiation therapy may provide local control, which is as effective as a more complete resection, however, without the morbidity of the more involved surgical procedure [16, 20, 22]. In this technique, the surgeon approaches and decompresses the neural elements such that there is a minimum critical distance between the residual tumor and the spinal cord, and radiation can be employed postoperatively. The patient therefore does not undergo an aggressive resection of the tumor, which will limit the operative time, blood loss, and potential need for reconstruction.

Other Concerns

After tumor resection, wound-healing concerns must be addressed. Perioperative radiation therapy as well as systemic chemotherapy may increase the risk of wound breakdown, wound infection, and poor healing. Plastic surgery consultation may be warranted for consideration of flap rotation, particularly in instances of revision surgery.

Part III: Case Illustrations

Hemangioma of C4

A 70-year-old female patient presented with the onset of axial neck pain and features of early myelopathy. Intake magnetic resonance imaging revealed a pathologic fracture of the C4 vertebral body, with retropulsed material effacing the ventral aspect of her cervical cord, and abnormal T2 signal apparent within the cord parenchyma. On CT, the lesion was noted to be osteolytic in nature, with significant loss of height and anterior wedging of the vertebral body. This imaging can be seen in Fig. 5.4. The patient had no history of malignancy and underwent CT-guided biopsy of the lesion, which was consistent with vertebral hemangioma.

Given the propensity for vertebral hemangioma to hemorrhage, the patient was taken for angiography. Feeding tributaries from the left thyrocervical trunk were found to provide the dominant source of irrigation of the lesion. Microcatheter runs can be seen in Fig. 5.5. Figure 5.5a represents the early arterial phase

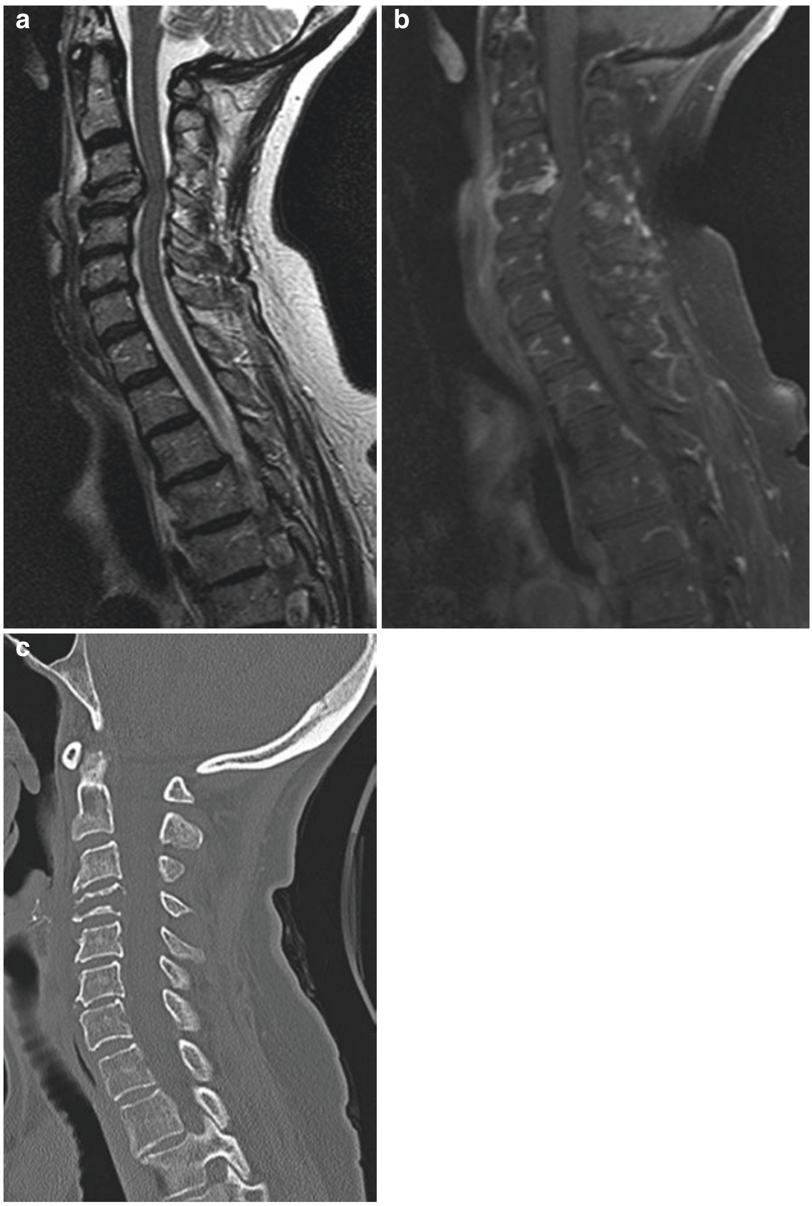

Fig. 5.4 (**a**) Preoperative imaging of a 70-year-old female with pathologic compression fracture of C4. Sagittal T2-weighted MRI. (**b**) Preoperative imaging of a 70-year-old female with pathologic compression fracture of C4. Sagittal T1-contrasted MRI. (**c**) Preoperative imaging of a 70-year-old female with pathologic compression fracture of C4. Sagittal CT

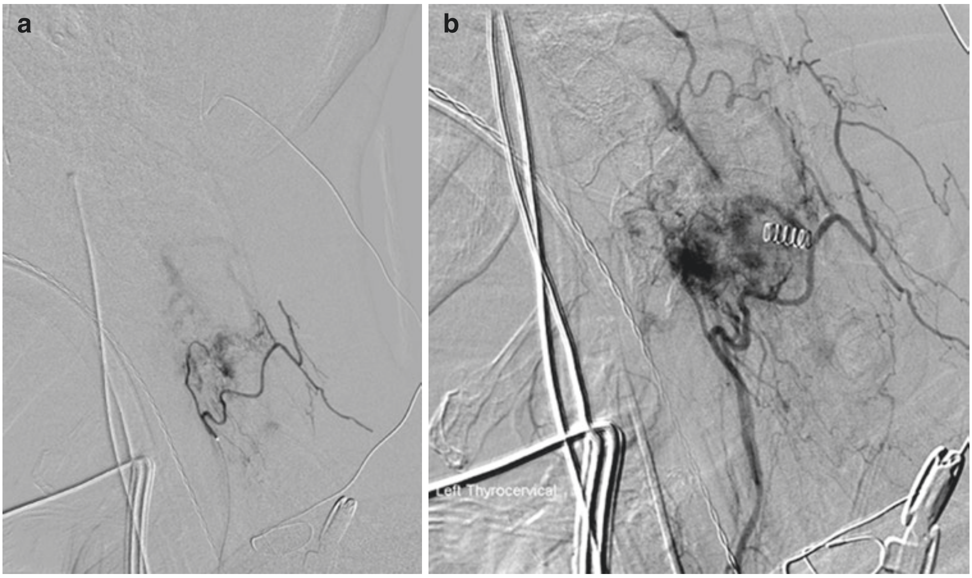

Fig. 5.5 (**a**) Angiography, early arterial phase, lateral projection, demonstrating arterial feeders from the thyrocervical trunk. (**b**) Angiography, late arterial and capillary phase, oblique working projection prior to embolization

on a lateral projection, whereas Fig. 5.5b represents a late arterial and capillary phase depicted on a more oblique working projection for pending embolization. Note the significant vascular blush of the tumor. The feeders were successfully embolized with Onyx® liquid embolic agent. The cast of embolic material can be seen on the lateral projection depicted in Fig. 5.6.

After angiography, the patient underwent a circumferential decompression and fusion, consisting of corpectomy of the C4 vertebral body followed by posterior arthrodesis from C3 to C5. Postoperative radiography is apparent in Fig. 5.7.

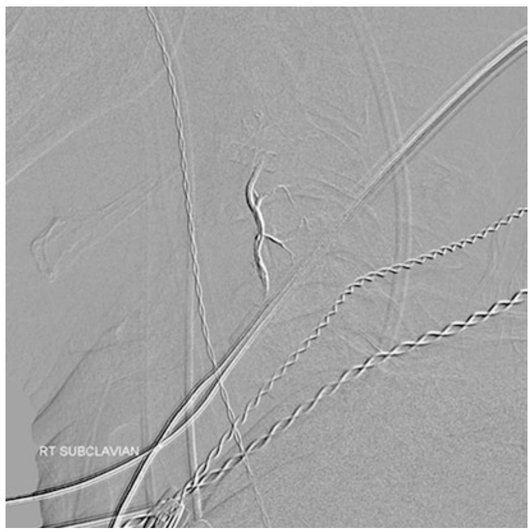

Fig. 5.6 Postembolization. Cast of the embolic material is apparent in the feeding artery, which originated from the thyrocervical trunk

Ventral Meningioma at C4–C5

A 55-year-old female initially presented with axial neck pain as well as radiculopathy of the right upper extremity. Imaging was notable for a calcified mass eccentric to the right side of the canal, dorsal to the C4 vertebral body, and spanning the C4–C5 disc space. A sagittal and axial computed tomography image is shown in Fig. 5.8. Given the ventral location of the lesion, the patient underwent a C4 corpectomy for exposure of the lesion. Intraoperatively, it was noted to be a partially calcified, dural-based mass. The lesion was resected along with its dural attachment. A patch duraplasty was performed, followed by insertion of an expandable corpectomy cage and anterior arthrodesis from C3 to C5. Finally, a lumbar drain was inserted. Final pathology was consistent with WHO grade I meningioma, psammomatous subtype. Postoperative lateral plain radiography is apparent in Fig. 5.9.

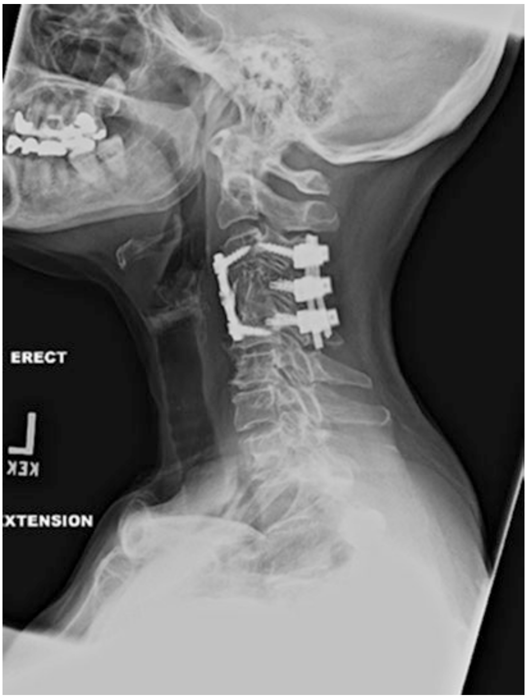

Fig. 5.7 The patient underwent C4 corpectomy with posterior augmentation. Pathology was consistent with vertebral hemangioma

Fig. 5.9 The patient underwent C4 corpectomy; pathology was consistent with WHO grade I psammomatous meningioma

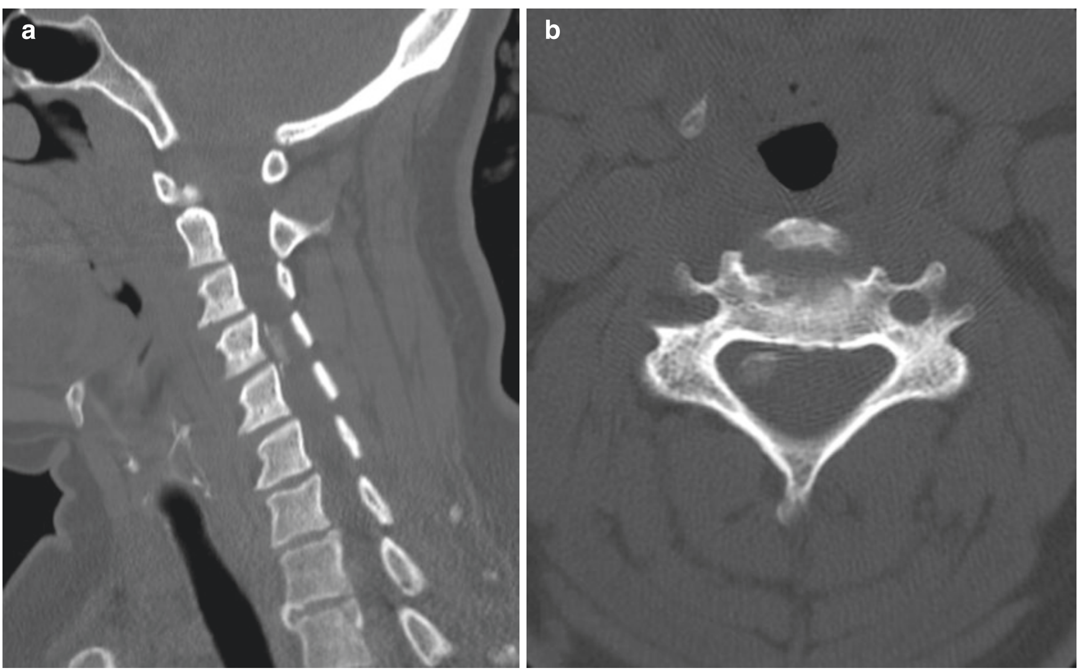

Fig. 5.8 (**a**) Sagittal CT demonstrating calcified mass dorsal to the C4 vertebral body. (**b**) Axial CT demonstrating calcified mass dorsal to the C4 vertebral body, eccentric to the right side

Cervical Chordoma

A 21-year-old female patient presented with progressive complaints of axial neck pain and right-hand clumsiness. Magnetic resonance imaging revealed a homogeneously enhancing, T2 intense epidural mass at the level of C3 through C5, exerting mass effect on the cervical spinal cord at these levels and extending out the right-sided neural foramina and into the anterior triangle of the neck. The lesion encased the right-sided vertebral artery. Figure 5.10 depicts the sagittal T2, sagittal T1 contrast-enhanced, and axial T1 contrast-enhanced MRI.

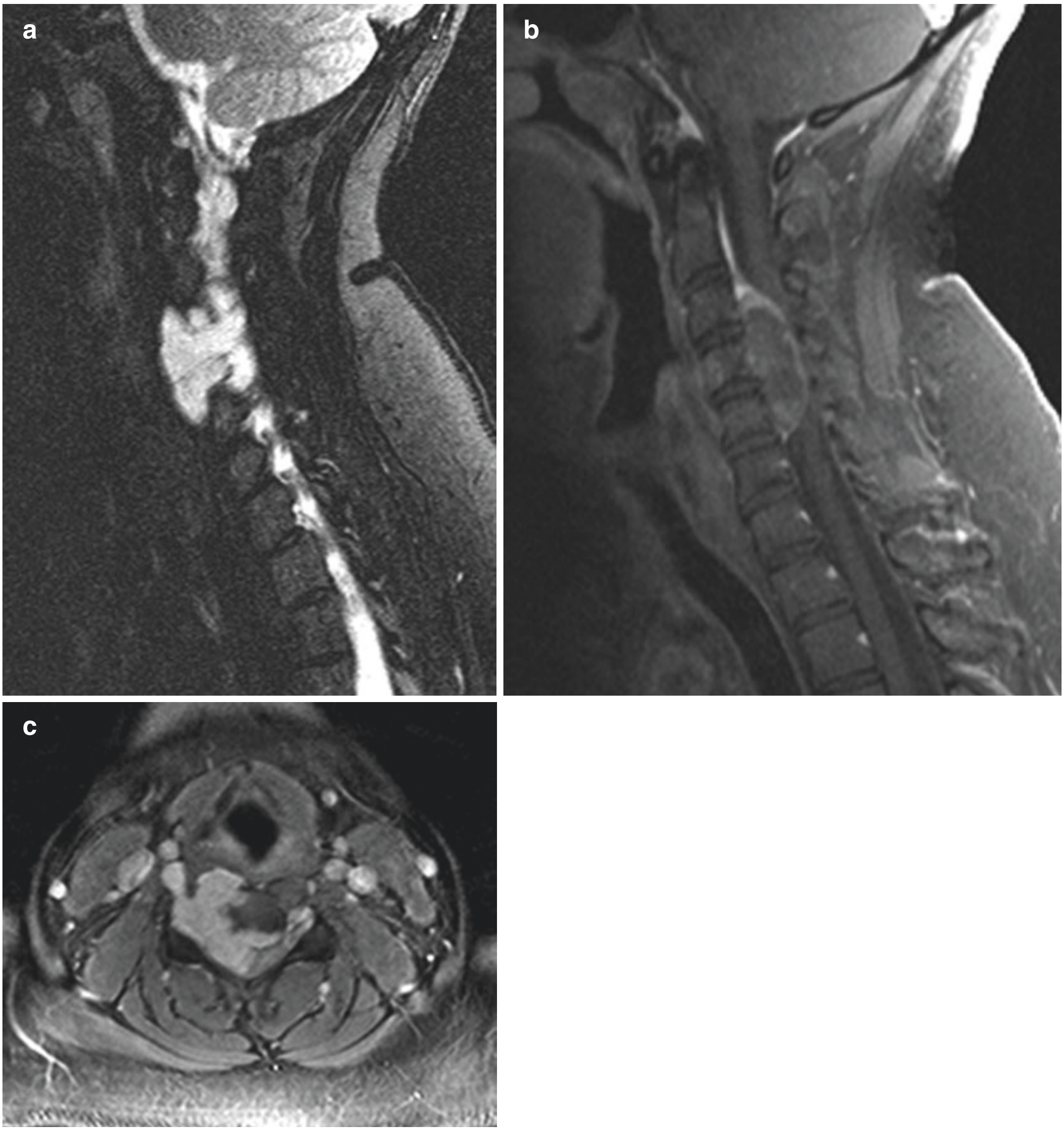

Fig. 5.10 (**a**) Anterior cervical epidural mass presenting in a 21-year-old female. Sagittal T2-weighted MRI. (**b**) Anterior cervical epidural mass presenting in a 21-year-old female. Sagittal T1-contrasted MRI. (**c**) Anterior cervical epidural mass presenting in a 21-year-old female. Axial T1-contrasted MRI

Computer tomography-guided biopsy was performed, and pathology returned consistent with chordoma. Given the encasement of her vertebral artery, the patient was taken for angiography and assessment of the collateral flow of her posterior cerebral circulation, along with test balloon occlusion of the right vertebral artery. She was found to have acceptable collateral flow, and the right vertebral artery was endovascularly sacrificed with Onyx® embolic material in order to facilitate en bloc resection of the chordoma. The postembolization Towne's projection of the left vertebral artery injection is shown in Fig. 5.11, which demonstrates the Onyx® cast within the right vertebral artery and appropriate collateral irrigation of the posterior circulation by the remaining left vertebral artery.

The patient next underwent a staged circumferential decompression, en bloc resection, and fusion procedure. The operation consisted of C3 through C5 corpectomy with anterior arthrodesis using a vascularized fibular free flap harvested and anastomosed in conjunction with plastic surgery, coupled with C3 through C7 laminectomy with right-sided C3 to C5 facetectomies, and C2 to T1 posterior arthrodesis. Postoperative CT is shown in Fig. 5.12. Figure 5.12a is a mid-sagittal

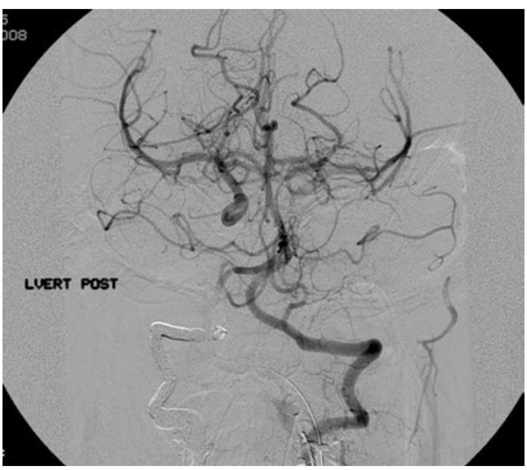

Fig. 5.11 Postembolization Towne's projection, left vertebral artery injection, demonstrating the Onyx® cast within the right vertebral artery and appropriate collateral irrigation of the posterior circulation by the remaining left vertebral artery

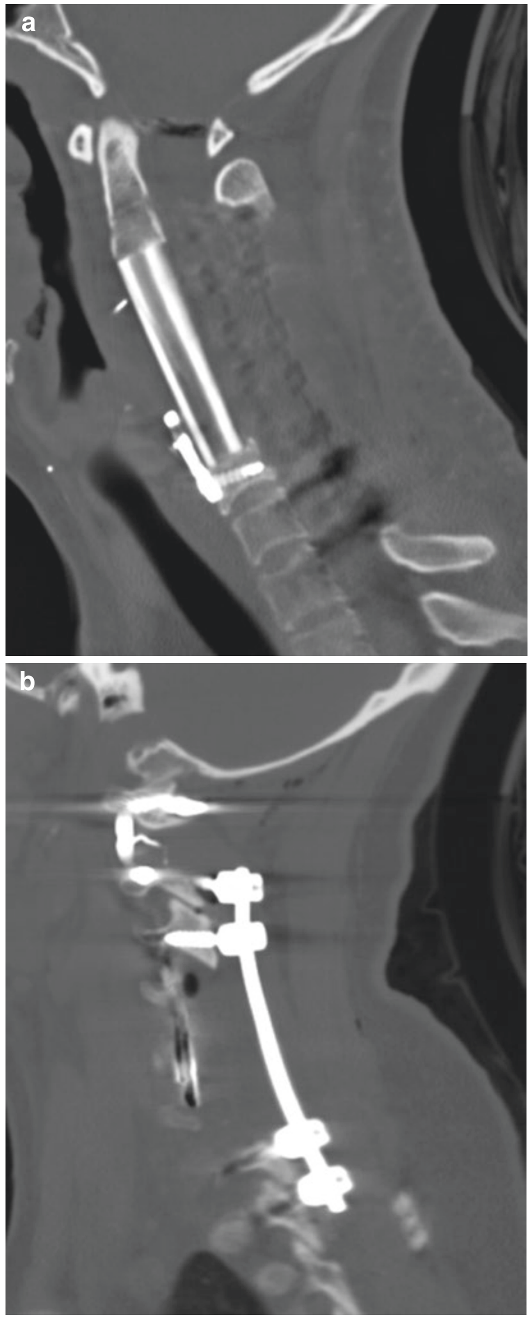

Fig. 5.12 (**a**) The patient underwent C3 through C5 corpectomy with anterior arthrodesis using a vascularized fibular free flap, coupled with C3 through C7 laminectomy with right-sided C3 to C5 facetectomies and C2 to T1 posterior arthrodesis. Sagittal postoperative CT. (**b**) The patient underwent C3 through C5 corpectomy with anterior arthrodesis using a vascularized fibular free-flap, coupled with C3 through C7 laminectomy with right-sided C3 to C5 facetectomies, and C2 to T1 posterior arthrodesis. Parasagittal postoperative CT

image demonstrating the position of the fibular graft. Figure 5.12b is a parasagittal image depicting the multi-level complete facetectomy. The patient tolerated the procedure well.

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