13 Posterior Subaxial Cervical Approach and Stabilization

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Introduction

The cervical spine can harbor many types of tumors, including primary bone malignancies and metastatic lesions (Table 13.1). Metastatic spinal cancers are far more prevalent than primary neoplasms. The spine is the most common site of skeletal metastases [1, 2] with an estimated 10% of cancer patients developing symptomatic metastases to the spine column [3]. Cervical spine metastases, though less prevalent than the thoracic and lumbar spine lesions, have been reported in up to 25% of patients with metastatic spinal tumors [1, 2, 4]. Approximately 85% of metastatic cervical tumors involve the subaxial spinal column [2, 5, 6]. Concomitant tumor involvement of the thoracolumbar spine is common [2, 6]. In contrast, primary tumors are rare and comprise less than 5% of all spinal column tumors [2].

Many tumors are discovered incidentally on radiographic studies or by physical examination findings. Symptoms may range from subtle stiffness or axial neck pain to more profound neurological deficits [2, 7]. Given the relatively wide spinal canal in the cervical spine, the incidence of neurological compromise is low, approximately 5% [2, 6, 8]. Neurological symptoms are typically due to extension of tumor into the spinal canal rather than deformity [2]. Severe night pain is a classic symptom that is often associated with cancerous neoplasms. Furthermore, a history of malignancy should raise clinical suspicion for potential recurrent or metastatic disease in patients with worsening or persistent neck pain. The etiology of axial neck pain may be a result of focal osseous destruction from the neoplasm or expansion of the periosteum. Osseous destruction can also lead to spinal instability resulting in pain on movement and increases the risk of a progressive kyphotic cervical deformity. Lesions that cause direct spinal cord or nerve root compression can also cause radiculomyelopathic symptoms. In severely stenotic cases, the spinal cord compression may result in quadriparesis.

The management of cervical spinal tumors depends not only on clinical presentation but also on histology, stage, and grade of the tumor. Although rare, primary tumors must be specifically addressed. Primary benign tumors are usually a focal problem but can be locally aggressive. Primary malignant tumors are always considered aggressive neoplasms. Because many primary lesions metastasize late, a radical en bloc tumor resection has potential to completely eradicate the disease [9–11]. If a primary lesion is suspected, a fine-needle biopsy can be performed to confirm the pathology. En bloc resections are technically challenging and are associated with

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Table 13.1 Classification of common tumors involving the spine

Benign primary tumors	Malignant primary tumors	Common metastatic tumors
Osteoid osteoma	Osteosarcoma	Lung
Osteoblastoma	Chondrosarcoma	Breast
Chondroblastoma	Hemangioendothelioma	GI tract
Hemangioma	Hemangiopericytoma	Prostate
Lymphangioma	Plasmacytoma, multiple myeloma	Melanoma
Giant-cell tumor	Lymphoma	Kidney
–	Leukemia	–
–	Chordoma	–
–	Ewing's sarcoma	–

significant morbidity and mortality. Conversely, aggressive en bloc resection of metastatic neoplasms is typically not indicated.

Nonoperative treatments with chemotherapy and/or radiotherapy may be effective in the initial stages of symptomatic cervical metastatic tumors [6], but surgery should be considered in patients who have failed nonoperative treatment or in patients who exhibit instability or neurological symptoms. Surgery is typically considered palliative in metastatic cancer patients. Surgery for metastatic spinal tumors does not alter the system disease, but local tumor control can improve the quality of the patient's remaining life with acceptably low mortality and morbidity rates [1, 4, 12–14]. The benefits of surgical intervention must be carefully weighed against the patient's estimated survival, their disease burden, their functional status, and the morbidity and recovery associated with the surgery. Together with adjuvant therapy, surgical intervention has the potential to provide symptomatic pain relief, reestablish spinal stability, and improve neurological status [1, 4, 12, 15].

Spinal tumors present complex surgical scenarios. In select cases a decompression alone may be sufficient, but in many instances a segmental fusion is required. Instability or prevention of iatrogenic instability is one of the major driving forces in adding a fusion construct to a tumor resection. In some circumstances instability can be noted preoperatively on flexion-extension lateral radiographs or if there is evidence of anterolisthesis of the vertebral bodies on computed tomography (CT) or magnetic resonance imaging (MRI). Patients who have lytic bony lesions, greater than 50% of vertebral body tumor involvement, evidence of vertebral body collapse, and destruction of the posterior facet joints have higher incidences of cervical instability. Finally, mechanical neck pain can also be a clinical indicator of dynamic spinal instability. Prophylactic fusion procedures are also performed in patients where postoperative instability or progressive deformity is anticipated. Situations that may predispose patients to worsening iatrogenic instability include combined anterior-posterior decompressions, extensive removal of ligamentous and bony structures, and multiple-level cervical laminectomies. An anterior decompression and reconstruction is useful in patients with extensive vertebral body tumor involvement or in patients who need support with axial loading of the spinal column. Posterior stabilization gives additional support to the posterior tension band and is best in tumors predominantly involving the posterior elements or dorsal epidural space. It is not uncommon for some cases to require a combined anterior and posterior approach to achieve appropriate tumor resection and fixation [16]. In these circumstances, posterior fixation provides additional stability to large anterior column resections. The use of lateral mass screw and rod constructs has become the gold standard method of providing posterior subaxial cervical spine fixation and stabilization.

Clinical Evaluation

Clinical evaluation of patients with a suspected spinal neoplasm should begin with a thorough history and physical examination. Diagnostic radiographic studies play a key role in investigation as they identify tumor anatomy and help narrow the differential tumor diagnosis. Appropriate studies for local assessment include plain radiographs, cervical computed tomographic (CT) scan, and magnetic resonance imaging (MRI). If a metastatic process is suspected, a chest radiographic as well as a CT scan of the chest abdomen and pelvis is indicated to evaluate for the primary lesion and to provide clinical oncological staging. A whole-body evaluation with positron emission tomography (PET) or bone scan should also be performed in patients with metastatic pathology to assess the overall extent of disease. The cervical MRI scan is helpful in determining the extent of local tumor involvement, differentiating tumor pathology, and assessing preoperative anatomy [2, 17]. Flexion and extension radiographs can be obtained to assess for dynamic instability. A cervical CT scan assesses bony integrity and shows viable screw options for cervical fusion constructs, if required.

Clinical Scenario

The patient is a 21-year-old Caucasian male who presents with a 3-week history of weakness and numbness of his bilateral upper extremities and a 3-day history of gait imbalance. His weakness is asymmetric with his left arm being more severely affected. He endorses constipation attributable to his current pain medicine regimen, but denies overt bowel and bladder incontinence. He has a history of osteosarcoma involving the distal right femur 5 years prior and has subsequently undergone tumor resection and endoprosthetic knee replacement. Since the time of his initial diagnosis, he developed a right-sided pulmonary nodule that was resected, and the pathology was consistent with metastatic osteosarcoma. On examination, he also has evidence of hyperreflexia in his lower extremities. An MRI evaluation revealed an enhancing epidural mass extending from C4 down to C7 that resulted in cervical spinal cord and nerve root compression (Fig. 13.1).

Positioning

Patient induction and surgical positioning warrant special consideration as many patients with cervical spine pathology have significant spinal canal stenosis [18]. Excessive neck flexion, extension, or rotation in this patient population has a potential risk for serious neurological complications. The head should be maintained in a neutral alignment until the head can be further secured. Similarly, fiberoptic intubation may reduce the amount of cervical extension required to place the endotracheal tube. The patient's blood pressure should be maintained at normotensive values, ideally with the systolic blood pressure being higher than 120 mmHg. Hypotension should be avoided in patients with spinal cord compression. Preoperative steroids can be considered if desired by the primary surgeon [19].

Neurological complications in the cervical spine can be potentially devastating, so preventative strategies such as intraoperative neurophysiological monitoring may be utilized to assess the psychological integrity of the spinal cord tracts. Monitoring the spinal column has potential to alert the surgeon prior to any irreversible neurological deterioration both during the positioning and the procedure [18, 20]. Combined motor evoked potential (MEP) and (somatosensory evoked potential (SSEP) monitoring can be used. The head should be kept in neutral alignment throughout the procedure and is secured to the bed frame with a Mayfield head holder.

Surgical Approach

Posterior cervical approaches begin with a midline incision over the intended levels of operation. The prominent C2 and C7 spinous processes can often be palpated to help with incisional planning, but fluoroscopy can be beneficial in smaller cases. The skin is incised sharply and the dissection is continued with electrocautery. The nuchal fascia is carefully dissected in line with

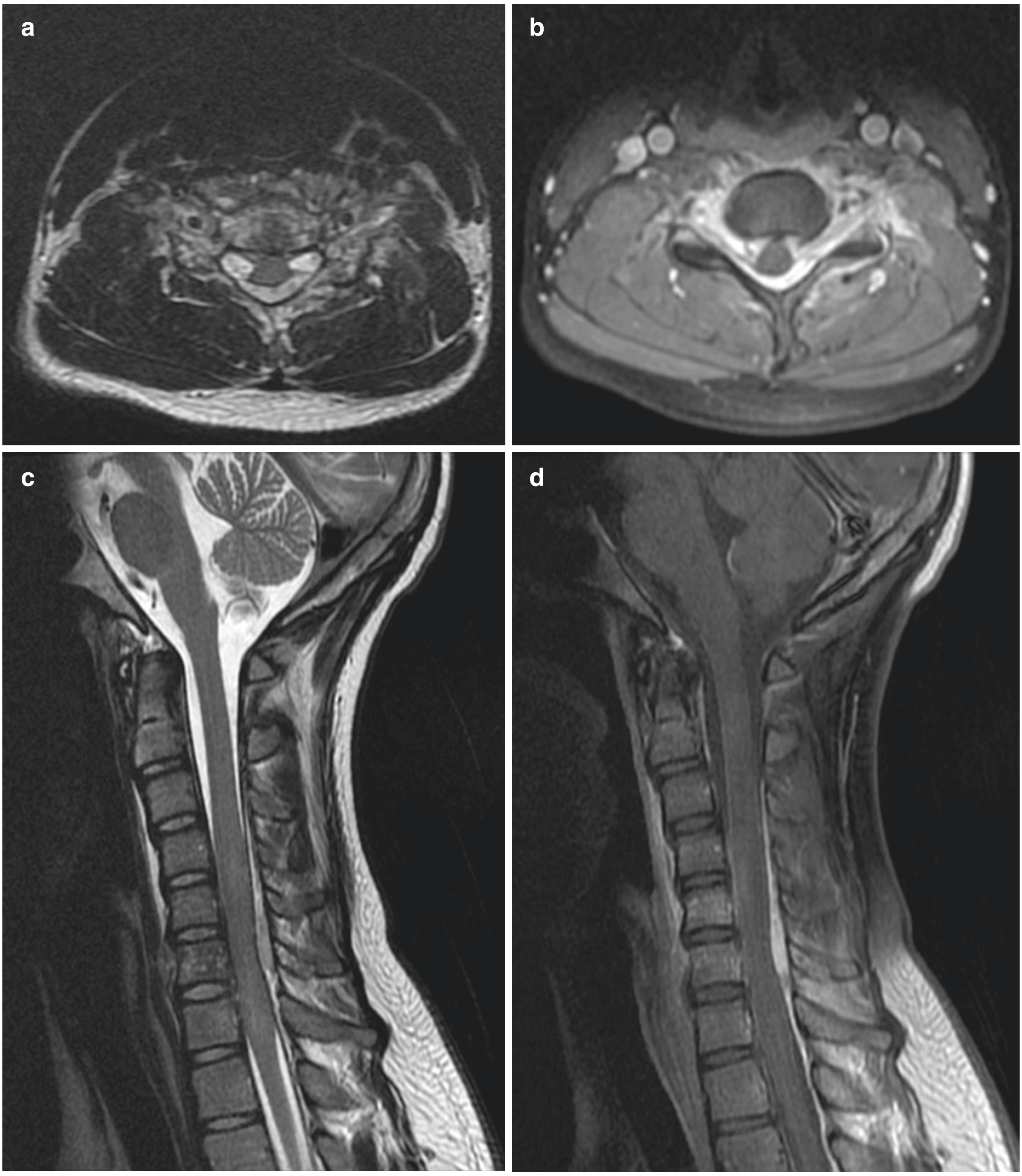

Fig. 13.1 MRI revealing an axial T2 (**a**), axial T1 with contrast (**b**), sagittal T2 (**c**), and sagittal T1 with contrast (**d**). There is evidence of epidural tumor involvement from C4 down to C7 resulting in moderate central spinal stenosis

the incision. The paraspinal musculature is then separated by identifying the relatively avascular midline raphe. Next, a subperiosteal dissection of the spinous processes, laminae, facet joints, and lateral masses is performed. The interspinous ligaments should be left intact when possible to help maintain stability. The intended levels of operation should be confirmed prior to any bone removal or instrumentation placement. Of note, the cervical facet capsules should not be violated until level localization has been verified radiographically to avoid unnecessary instability or autofusion of joints outside of the intended fusion construct.

Decompression and Tumor Resection

Resection of spinal tumors can be challenging. Surgical tenets such as adequate exposure, gentle tissue manipulation, continuous hemostasis, and approaching the lesion from normal to abnormal anatomy are vital. Goals of surgery vary widely depending on tumor pathology, extent of systemic disease, and patient health. If the lesion is a primary bony neoplasm, an aggressive en bloc resection with margins is desirable. Metastatic lesions are most often resected piecemeal, and surgery is considered palliative in this population. Regardless, the first priority is decompression of the neural elements, and this goal is often best achieved with a laminectomy. Multiple cervical laminectomy techniques have been described in the literature. One method involves drilling bilateral troughs along the laminar facet interface and removing the spinous processes and lamina in an en bloc fashion. Alternatively, the high-speed drill can be used to drill away the lamina while leaving an eggshell of thin cortical bone on top of the canal, which can then be removed with rongeurs. To ensure adequate decompression, the laminectomy should extend superior and inferior to the compressing lesion. Most operative patients with metastatic spinal tumors have some degree of spinal canal compromise, placing the patients at higher operative risks. In these circumstances, expedient tumor debulking can prevent any prolonged spinal cord compression during the procedure. Early decompression is especially important if monitoring changes occur. However, if spinal impingement is not a concern, performing screw placement prior to the decompression is reasonable.

The major limitations that can hinder tumor resection include involvement of the spinal dura, nerve roots, and vertebral arteries. Unlike spinal surgeries for degenerative pathology, oncological surgery often requires extensive bony removal of the posterior elements to adequately resect tumor and decompress neural elements. This enhances visualization of the spinal canal and exiting nerves and provides a corridor for tumor resection. However, excessive removal of the lateral mass and facet joints impairs axial loading, and in extreme cases, lateral mass reconstruction can be considered using a fibular strut or cage if there is competent bone above and below the defect to support the reconstruction [21].

Intraoperative bleeding can be excessive in patients with hypervascular spinal column tumors. Certain tumor pathologies such as renal cell carcinoma have a higher propensity for hemorrhage. Preoperative embolization of the feeding arteries can be helpful in reducing blood loss [2, 22–25]. However, embolization is rarely sufficient to stop bleeding altogether. Continued bleeding is often a result of residual tumor, especially in piecemeal resections, and the bleeding often slows upon completion of the tumor resection. Hemorrhagic areas can often be controlled with manual tamponade techniques using a cottonoid and gentle pressure from a suction device or the use of hemostatic agents.

In the provided scenario, the tumor predominantly involved the epidural space posteriorly. Laminectomies were performed from C4 to C7, exposing the underlying tumor. The lateral mass and facet joints were preserved. A surgical plane between the tumor capsule and spinal dura was identified and teased apart. The tumor was then resected in a piecemeal fashion until no remaining tumor was visible and all neural structures were adequately decompressed.

Fusion

Fusion procedures are often performed concurrently with tumor resections to prevent progressive deformity in the setting of pathologic or iatrogenic spinal instability. Having a firm knowledge of cervical anatomy and any pathological changes secondary to tumor displacement is pivotal in reducing fusion complication rates (Fig. 13.2).

While there have been many stabilization methods described in the literature, lateral mass screw constructs have become the gold standard for posterior cervical spine fixation (Fig. 13.3) [18, 26–28]. Three common lateral mass screw techniques have been described, the Magerl, the

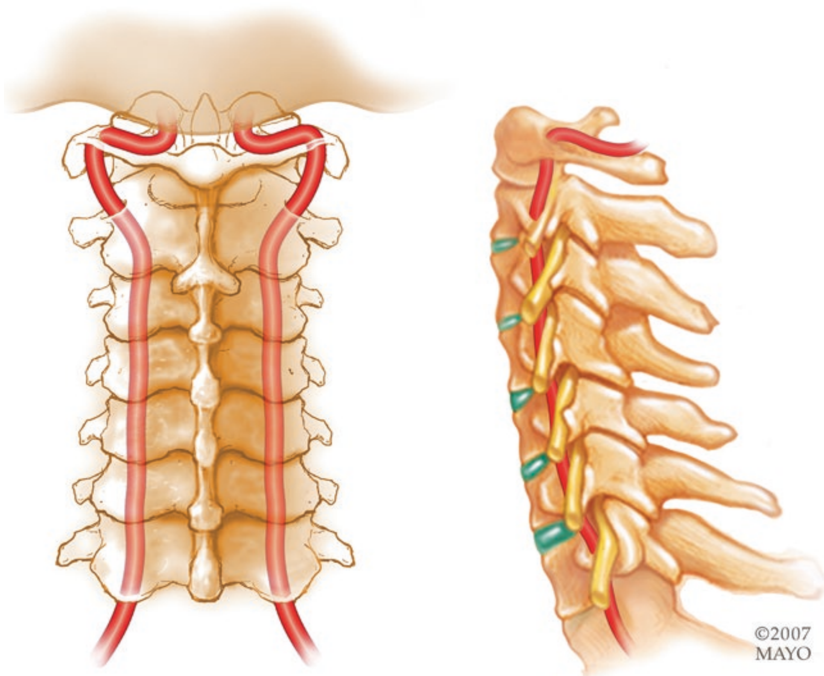

Fig. 13.2 AP and lateral views of the cervical spinal column referencing typical vascular and nerve anatomy. (Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved)

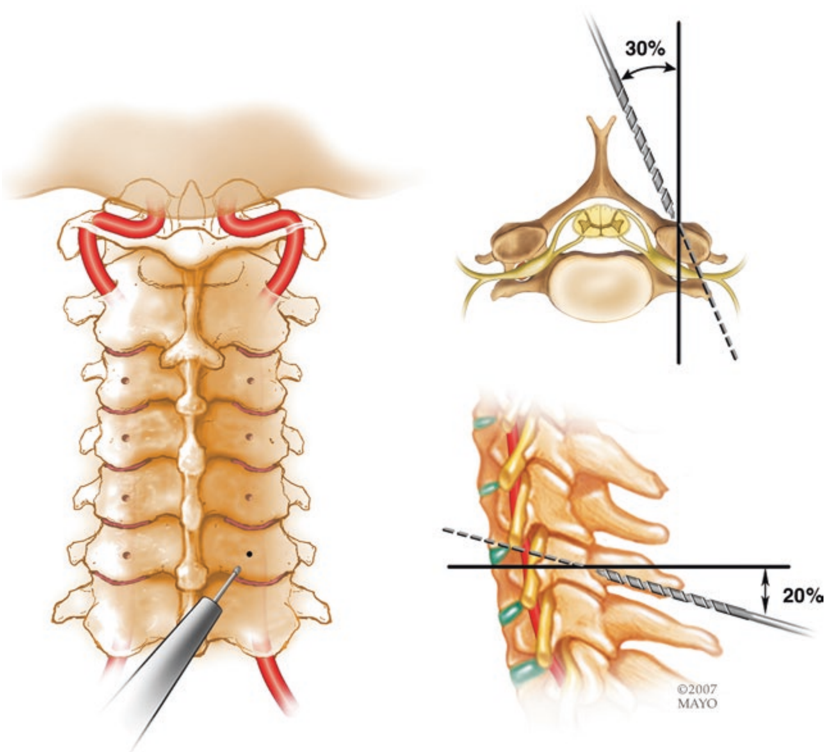

Fig. 13.3 Standard entry point location and lateral mass screw trajectory. (Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved)

An, and the Anderson techniques. These techniques vary slightly on entry point and screw angulation, but are all similar in that they aim laterally to avoid injury to the vertebral artery and cephalad to avoid the exiting nerve root [18, 27].

Once the lateral mass landmarks are well visualized, the entry point is identified and a pilot hole is created. Using a high-speed drill, lateral mass tracts are cannulated utilizing a superior and lateral trajectory until the lateral mass floor can no longer be palpated with a ball probe. The tract is under-tapped. The depth is often between 12 and 16 mm depending on the presence of osteophytes, patient's body habitus, and the exact surgical trajectory that was taken.

Ending instrumentation at the C7 vertebral level is somewhat controversial as it creates long-arm vector forces between the cervical fusion and the physiological stiff thoracic spine, increasing the likelihood of adjacent segment disease. Longer cervical constructs are often extended to the upper thoracic spine to bridge the cervicothoracic junction to increase stability and avoid this complication (Fig. 13.4).

In patients with poor life expectancy, spinal stabilization alone may be appropriate, but if patients have a more indolent pathology or have a longer life expectancy, obtaining a solid fusion is preferred (Fig. 13.5). The facet joints and lamina should be exposed and decorticated with a cutting bit. Fusion preparation should be performed prior to lateral mass screw insertion as the screws can often inhibit visualization and drill access to the subaxial facet joints

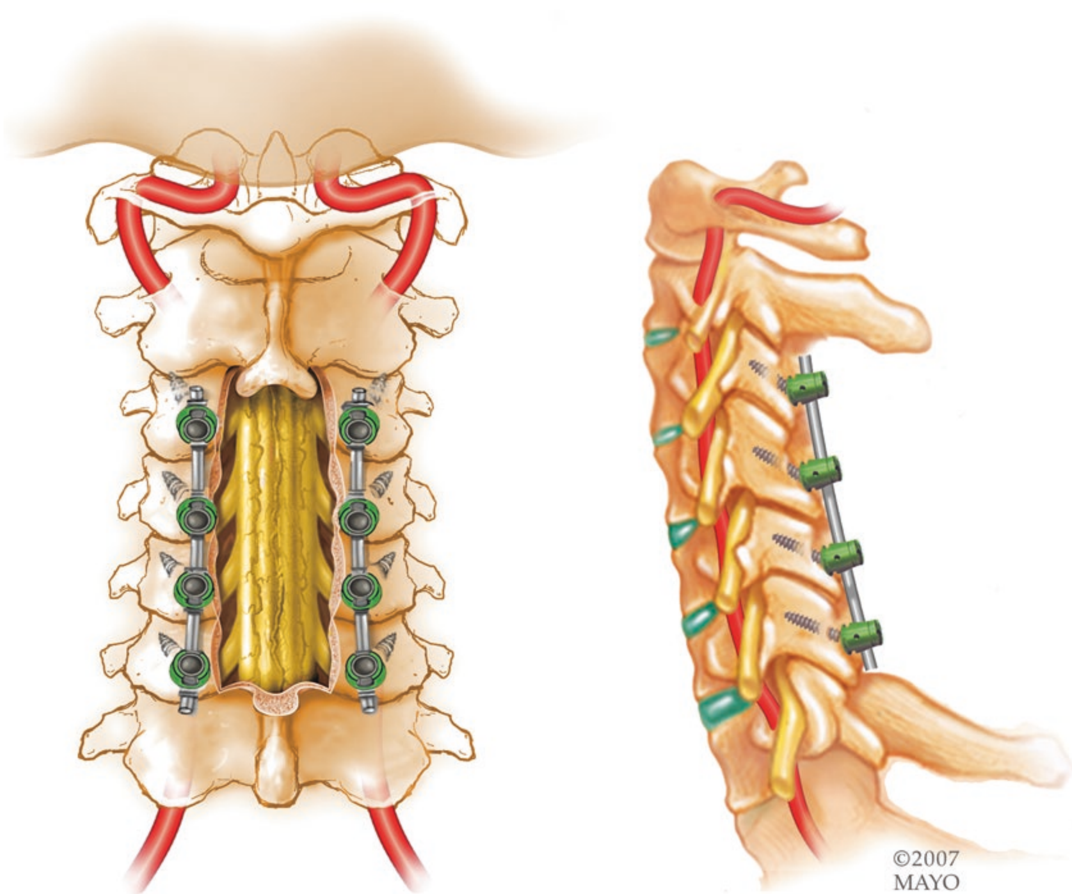

Fig. 13.4 AP and lateral view of subaxial laminectomies and fixation from C3 to C6. (Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved)

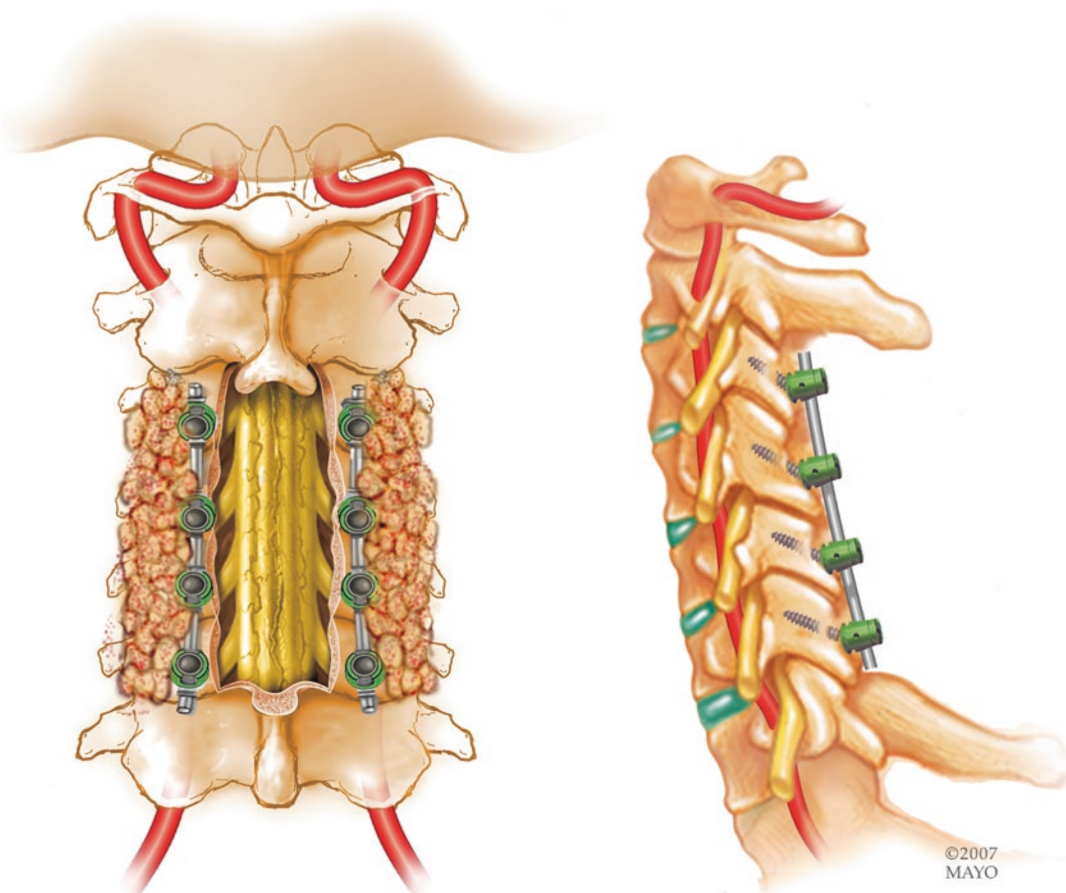

Fig. 13.5 AP and lateral view of subaxial fusion following arthrodesis. (Used with permission of Mayo Foundation for Medical Education and Research. All rights reserved)

[18]. The wound should be copiously irrigated prior to placement of graft materials. Polyaxial lateral mass screws are inserted. Excessive torque should be avoided as this can result in fracture of the lateral mass or strip the screw tract, reducing the bony purchase of the screw. Cervical alignment and screw position should be confirmed with a lateral radiograph or fluoroscopy. Finally, iliac crest autograft (if not involved by tumor) or cadaveric allograft is inserted into the decorticated facet joints and fusion bed to promote arthrodesis. Local bone autograft is typically not harvested in patients with active neoplastic lesions as the bone fragments could be seeded with cancerous cells, increasing the likelihood of local tumor recurrence or spread during arthrodesis. There should not be any free bone fragments in the spinal canal as this is a potential source of nerve compression.

Purely subaxial fixation is acceptable in certain cases. However, our clinical scenario had extensive epidural tumor involvement from C4 to C7 requiring multilevel laminectomies to resect the tumor. Therefore, the fusion captured C2 superiorly and was extended inferiorly to T2 to bridge the cervicothoracic junction and provide additional stability (Fig. 13.6). Thoracic pedicle screws and C2 screws are both outside the scope of this chapter. See Chaps. 12 and 17 for additional information on these techniques. It is also notable that the fusion construct in this case extends beyond the area of anticipated postoperative radiation treatment.

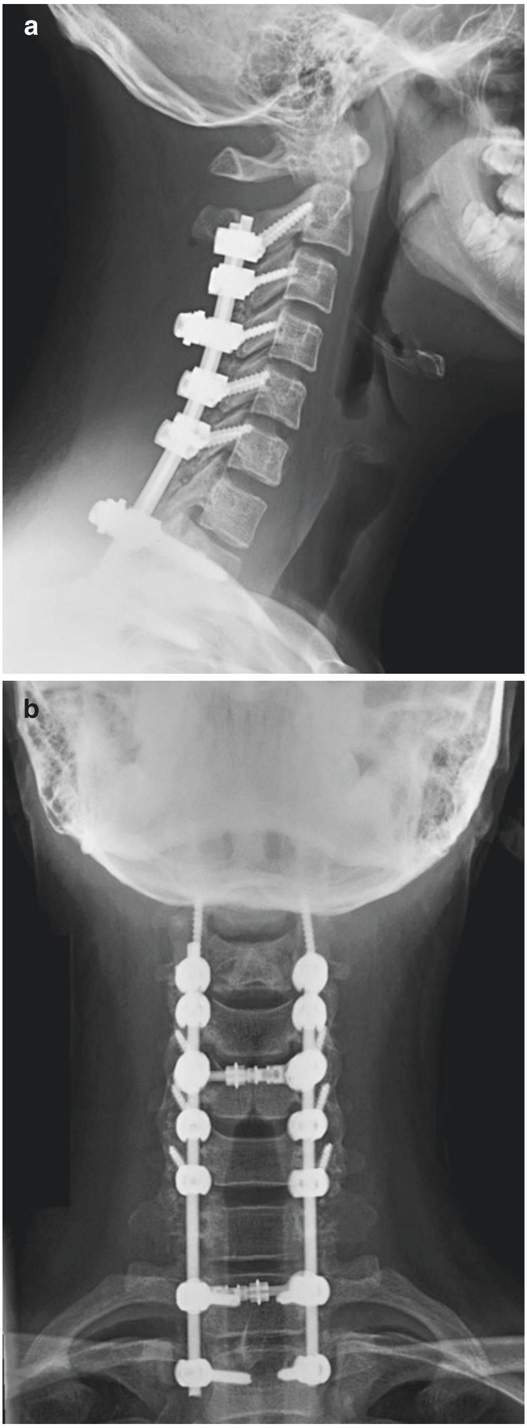

Fig. 13.6 Postoperative AP (**a**) and lateral (**b**) views of a C2–T2 posterior instrumented fusion with cross-links

Closure

A meticulous closure technique is important to minimize wound complication. Excellent hemostasis should be achieved prior to closing the wound. The extensive osseous decortication performed for arthrodesis often results in ongoing postoperative blood loss; therefore, subfascial and suprafascial drains are often placed.

Complications

The literature has shown that patients with spinal cancers have higher rates of surgical morbidity and mortality [3, 10, 29]. Optimizing outcomes in spinal tumor patients focuses on preservation of function and prevention of complications that can delay life-prolonging adjuvant treatments. Surgical site infections and wound complications are prevalent. Risk factors for wound complications include preoperative radiation and poor nutritional status [3]. Wound infections are highly problematic for cancer patients as this often requires additional surgery for irrigation and debridement, which temporarily suspends ongoing systemic chemotherapy and radiation treatments [3, 30]. Some studies have suggested that intraoperative vancomycin powder can reduce wound infection rates [31–33], but there is little evidence available to support this practice in cancer patients. Surgery is frequently followed by postoperative radiation, which can further impair wound healing and spinal fusion rates [3, 30]. Radiotherapy should be delayed for at least 2 weeks or more to minimize wound-related complications [34]. Furthermore, poor bone quality associated with the lesion or preexisting osteopenia or osteoporosis has been associated with higher rates of instrumentation failure in spinal tumor patients [30]. Finally, cancer patients are often hypercoagulable and are predisposed to deep venous thromboses, pulmonary emboli, or even disseminated intravascular coagulation [30]. Sequential compression devices and early mobilization are key to reducing the incidence of thrombotic complications in cancer patients.

There are inherent risks associated with posterior cervical lateral mass screw instrumentation as well. The structures most at risk during screw placement are the vertebral artery and the exiting nerve root. The screws should be directed laterally to avoid vascular injury to the vertebral artery, which typically lies ventral to the medial half of the lateral mass. If a vascular injury occurs during drilling, a short screw can be inserted along the tract to tamponade the arterial bleeding. Alternatively, the tract can be plugged with bone wax for hemostasis. Additional drilling of bone for visualization or any attempt to directly repair the vascular injury is not recommended as this may result in uncontrollable bleeding. If there is suspicion of vertebral artery injury, it is essential to avoid additional maneuvers that might put the contralateral vertebral artery at risk. Immediately following the procedure, the patient should undergo a diagnostic cerebral angiography for vascular assessment. If any ongoing bleeding or vascular dissection is identified, it can be further addressed in the angiography suite. Delayed cervical palsies are also a common complication following posterior cervical decompressions and most often occur in the C5 dermatome [35, 36]. Most patients make a full neurological recovery; however, it often takes up to 6 months or more to see maximal improvement [18]. Any patient who has radicular symptoms postoperatively should have advanced imaging performed to assess screw positioning and nerve root integrity.

If electrophysiological monitoring is being utilized, surgeons must know how to interpret and correct persistent monitoring changes. If a focal monitoring change is present, extremity repositioning can improve monitoring signals. Monitoring checks should be performed before and after any cervical deformity correction maneuvers are performed. If a monitoring change occurs following a correction in spinal alignment, it is recommended to reverse or lessen the degree of deformity correction.

Uncontrollable intraoperative hemorrhage from spinal tumors is a rare but potentially devastating intraoperative complication. Patients with metastatic cancer often have intrinsic coagulation dysfunction due to their systemic disease, and some lesions also have extensive involvement of local vascular anatomy. Certain tumor histologies, such as renal cell carcinoma, follicular thyroid carcinoma, and neuroendocrine tumors, have a higher propensity for intraoperative hemorrhage. If intraoperative bleeding is a concern, angiographic embolization can be performed to reduce intraoperative blood loss and provide better intraoperative visualization [2–25, 30]. Of note, intraoperative blood salvage is often avoided due to the risk of metastatic tumor contamination.

Clinical Pearls

Preoperative radiographic anatomy should be extensively reviewed to assess the extent of tumor involvement and to evaluate for aberrant vascular anatomy. Notify anesthesia prior to induction about cervical stenosis and implement standard positioning precautions of the cervical spine. Primary bony neoplasms require an aggressive en bloc surgical resection for surgical cure. Conversely, surgery for patients with metastatic spinal disease is palliative and is reserved for patients with intractable pain or neurological compromise. Lateral mass screws are recommended for posterior cervical constructs, and they should be directed laterally and superiorly (parallel to the facet joints) to avoid injury to the exiting nerve roots and vertebral artery.

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