5 Cervical Osteotomy

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Techniques for spinal osteotomy have evolved over the past 75 years, and although basic principles remain the same, certain technical advances have occurred. Smith-Petersen et al. (7) were among the first to describe such techniques with their series of posterior lumbar osteotomies in 1945. LaChapelle (2) followed soon thereafter with his description of staged anterior and posterior lumbar osteotomies in 1946. Mason et al. (3) described his osteotomy of the cervical spine in 1953.

In 1972, Simmons (6) popularized the idea that cervical osteotomy could be performed in ankylosing spondylitis (AS) patients under local anesthesia with continuous neurologic monitoring. Urist (8) is credited with first describing this awake-sitting technique under local anesthesia in 1958. Urist also recommended that the osteotomy occur at the C7–T1 junction if possible. There are several benefits of performing the osteotomy at the cervicothoracic junction: (a) the spinal canal is relatively wide with more space available for the neural elements, (b) damage to the cord and/or nerve roots at this level would be less catastrophic than if in the midcervical region, and (c) the risk of injuring the vertebral artery is less, as the artery typically passes anterior to the transverse processes in this region.

Simmons (6) advocated a posterior wedge-shaped osteotomy to perform the correction. Removal of the lamina and spinous processes from C6 to T1 is done. Facetectomies are performed bilaterally to widely expose the C8 nerve roots. The head is extended in order to perform an osteoclasis of the anterior and middle columns of the cervical spine with the instantaneous axis of rotation at the base of the C7 pedicle. This causes lengthening of the anterior spine while the posterior elements are shortened. No instrumentation was used, and a halo was applied until fusion occurred. This technique was associated with a 4% mortality and 2% incidence of nerve root lesions.

Bohlman (1) expanded on Simmons' cervical osteotomy technique with the addition of instrumentation to stabilize the cervical spine after the osteotomies were performed. Bohlman utilized a small Luque rectangle with Drummond wires and buttons supplemented by autograft. Patients, however, were still immobilized postoperatively in halo vests. Like Simmons and Urist, Bohlman preferred to perform his osteotomy at the C7–T1 junction.

In order to limit the possibility of sagittal translation during the Simmons osteotomy technique, Mehdian and Arun (4) devised a more controlled method of reduction at the osteotomy site. The Mehdian method involves the use of a posterior cervicothoracic screw-rod system that is implanted prior to completion of the osteotomy. Provisional, malleable rods are temporarily inserted. These rods allow the thoracic pedicle screws to slide along the rod as the reduction is performed without allowing translation. This allows for a more controlled reduction maneuver before the definitive titanium rods are placed.

INDICATIONS/CONTRAINDICATIONS

The primary indication for cervical osteotomy is the correction of a fixed cervical kyphotic deformity. This can occur in patients with AS, previous trauma, or prior surgery. This deformity may result in difficulty with activities of daily living, respiratory compromise, difficulty eating, loss of horizontal gaze, and/or disabling pain. Cervical osteotomy is contraindicated when the major deformity is in the thoracolumbar spine, when a flexion contracture of the hip is present, or if the cervical kyphosis is flexible. Other general contraindications include significant medical comorbidities that would prohibit normal recovery and rehabilitation.

PREOPERATIVE PREPARATION

Patient Evaluation

Medical comorbidities should be noted, evaluated, and optimized. Special attention should ensure that the cardiopulmonary status of the patient is satisfactory to undergo a spinal reconstructive procedure. Patients with AS, for instance, often have significantly restricted chest expansion due to ankylosed costovertebral joints. The surgeon should be aware of such issues.

Routine preoperative lab work should exclude anemia and coagulopathy. We recommend a lengthy discussion with the patient regarding the potential risks and benefits of surgery. Major surgical risks of cervical osteotomy include dysphagia, infection, malunion, nonunion, neurologic injury, vertebral artery injury, and death.

Preoperative Radiographic Evaluation

Cervical kyphotic deformities can occur at any age and may be associated with thoracic and/or lumbar deformities. It is important, therefore, to look at global sagittal and coronal balance (with full-length PA and lateral 36-inch scoliosis x-rays) in these patients to ensure that the planned correction does not cause decompensation in overall spinal balance (Fig. 5-1). You must assess cervical, thoracic, and lumbar sagittal alignment individually as well as globally and define the site of maximal deformity. The degree of correction to be obtained depends on the angle of the cervical deformity and the chin-brow to vertical angle. Meticulously plan the procedure on printed or digital x-ray including the size of the osteotomy and hardware position. Determination of osteotomy size/angle can be done via radiographic tracing and film cutout or simple mathematical calculation (5). Planning is crucial to ensure you do not overcorrect the deformity. In addition, we recommend preoperative radiographic evaluation with computed tomography (CT), and magnetic resonance imaging (MRI). Sagittal and coronal reconstructions are helpful to better visualize the deformity. The CT scan is useful to measure the dimensions of the vertebral bodies, the cervical pedicles, and the cervical lateral masses. This information is crucial for selection of the appropriate implants and accurate planning. The MRI is useful to evaluate not only spinal cord and nerve root compression but also size and position of the vertebral arteries.

Fig. 5-1

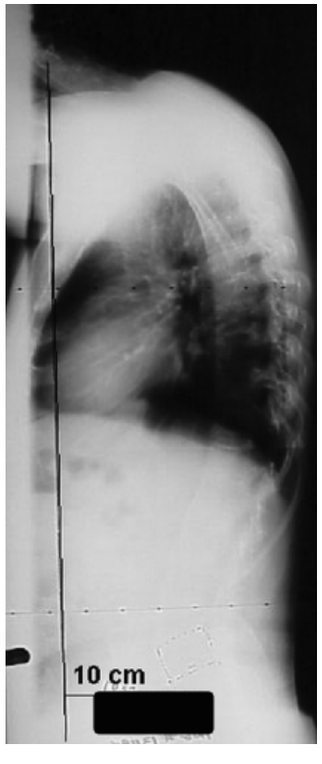


FIGURE 5-1

Lateral standing radiograph demonstrating significant sagittal imbalance with the C7 plumb line approximately 10 cm anterior to the sacral promontory.

TECHNIQUE

Anesthetic Considerations

Intubation of a patient with a significant cervical deformity can be challenging. A real potential exists for spinal cord injury during intubation, as well as throughout the case due to hemodynamic changes or direct cord injury. Consequently, modern anesthetic techniques involve monitoring the cardiovascular and neurologic status of the patient. To this end, arterial line placement and motor evoked (MEP) and somatosensory evoked potentials (SSEP) are recommended to monitor blood pressure and spinal cord integrity respectively throughout the case. Subclavian central line placement for monitoring the central venous pressure can also be done if deemed necessary. We caution, with regard to neuromonitoring, that SSEPs are not always accurate and there have been cases where changes in evoked potentials have not been accompanied by changes in neurologic status (i.e., false positives). There have also been cases where a neurologic injury occurred without accompanying changes in the evoked potentials (i.e., false negatives).

One relatively safe method of intubation is awake, nasotracheal, fiberoptic intubation. Performing the intubation awake is important because the patient's neurologic status can be continuously assessed. The abnormal fixed chin-brow vertical angle does not allow for the patient's head to be extended, and fiberoptic intubation is necessary to visualize the vocal cords and ensure appropriate placement of the endotracheal tube. Orotracheal intubation with a chin-on-chest deformity is difficult at best due to restricted access to the oral cavity. Nasotracheal intubation is easier and can proceed after the nasal cavity has been anesthetized.

The choice of anesthetic agents is critical when evoked potentials are utilized. Paralytics and nitrous oxide are not used in these cases as they blunt the MEPs and SSEPs respectively. Total IV anesthesia is ideal in the setting of neuromonitoring.

It is important to obtain pre– and post–general anesthesia baseline readings of the evoked potentials. Since changes in the anesthetic regimen can cause changes in the evoked potentials, we do not recommend changing the drugs or dosages throughout the case.

Ensuring adequate spinal cord perfusion throughout the case is crucial. The patient's mean arterial pressure (MAP) prior to intubation is assessed, and this MAP is maintained throughout the case (even in the face of blood loss). We do not hesitate to use transfusions and/or pressors as needed throughout the case to maintain the MAP.

Osteotomy Considerations

Numerous osteotomy techniques have been described as previously mentioned. All include some variation of opening versus closing wedge osteotomy. We will describe two cervical techniques felt to be the most efficacious and biomechanically sound depending on where the apex of the deformity occurs. The majority of deformities involving the cervical region are most severe at the cervicothoracic junction, which is also an ideal place for the osteotomy due to the reasons discussed earlier. Deformities, however, may be within the actual cervical region and necessitate osteotomy above the cervicothoracic junction.

CERVICOTHORACIC PEDICLE SUBTRACTION OSTEOTOMY

Stage I—Positioning

After induction of anesthesia, a Foley catheter, sequential compression stockings, and pneumatic compression devices are applied. Baseline readings of SSEPs and MEPs are obtained before positioning the patient. The preoperative x-ray with the operative plan is hung in the operating room for all physicians and assistants to reference.

The patient is placed in Mayfield pins while in the supine position. The Jackson table is set up such that the foot of the bed is placed at the lowest rungs and the head of the bed at the highest rungs. The patient is then transferred to the prone position on the Jackson table. Due to the significant kyphotic deformity, positioning can be a challenging task. In order to raise the head into the operative field, blankets can be used to elevate the chest. A second option involves removing the hip pads on the table and using the leg sling only provided the patient's body habitus allows the pelvic region to pass between the bars of the table. Arms are secured at the patient's side with a circumferential sheet and towel clips. The head is secured to the table by attaching to the Mayfield head holder. The patient's buttocks should be taped to the table to prevent distal migration of the patient on the bed. The shoulders are taped to aid with imaging. The table is placed in reverse Trendelenburg to also aid with elevation of the head into the operative field.

It is important that the surgeon pay close attention to the plane of the patient's body in relation to the floor. The chin-brow vertical angle should be noted, and this angle should be corrected, allowing the face to be parallel to the plane of the body. It is better to slightly undercorrect the deformity than to overcorrect. After positioning is complete, repeat SSEPs and MEPs are performed to ensure integrity of the spinal cord.

The posterior cervicothoracic region is prepped and draped in the normal sterile fashion. A permanent surgical marker is used to outline the incision prior to draping. It is best to drape wide from the occiput down to the midthoracic region.

Stage II—Exposure and Instrumentation

A standard posterior cervical exposure is performed. The lateral masses in the cervical region are fully visualized as are the transverse processes in the thoracic region. Care is taken at both the proximal and distal extent of the fusion area to protect the facets and posterior ligamentous complex in hopes of avoiding iatrogenic adjacent level problems (Fig. 5-2).

Lateral mass screws are inserted in the cervical region via the Magerl technique. The starting point is in the middle of the lateral mass, and the trajectory aimed at the upper and outer quadrant of the lateral mass. We typically use 14-mm screws that are placed unicortically.

Upper thoracic pedicle screws are placed via standard anatomic landmarks. The craniocaudal entry point is at the junction of the upper and middle third of the transverse process, and this point is usually approximately 3 mm below the facet joint itself. The mediolateral entry point is at the center of the facet joint. In addition, a laminoforaminotomy may be performed to allow the surgeon to visualize and palpate the medial border of the pedicle. Use of image guidance can also assist with placement of the thoracic screws. Use a high-speed drill to burr the posterior cortex at pedicle screw entry points. Typically, a bleeding area of bone (this is the cancellous bone within the pedicle) is exposed with this maneuver. We then utilize the awl and tap to enter the pedicle. These instruments usually pass down the pedicle with minimal force without perforating the pedicle walls. Pedicle screws are then placed.

Next we attach provisional rods to the lateral mass and thoracic pedicle screws. The provisional rods are hollow stainless steel tubes that are fairly easy to bend, thus allowing sagittal plane correction while preventing translation. These provisional rods are attached to the polyaxial screw heads with small lateral connectors. The lateral attachment of the provisional rods is necessary to allow for the upcoming posterior wedge osteotomy of the cervical facets. Locking caps are placed and tightened to secure the connectors to the polyaxial screw heads. Locking caps are also used to secure the connectors to the rods; however these are not tightened, allowing the connectors to translate along the rod during deformity correction (Fig. 5-3).

Stage III—Osteotomy

The osteotomy begins with a complete laminectomy of C7, removing the entire spinous process and lamina. The inferior half of the C6 lamina and superior half of the T1 lamina are removed. If needed, the caudal and cephalad aspects of the spinous processes of C6 and T1 respectively, can also be removed. The C7 lateral mass must be completely removed as well as the transverse process laterally. The inferior facets of C6 and the superior facets of T1 are also removed flush with the edge

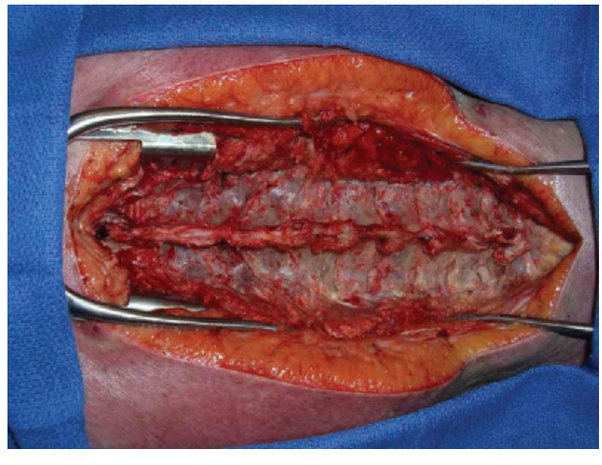


FIGURE 5-2

Complete exposure is performed of the lateral masses within the cervical region and ~~the~~ out to the transverse processes within the upper thoracic region.

Q3

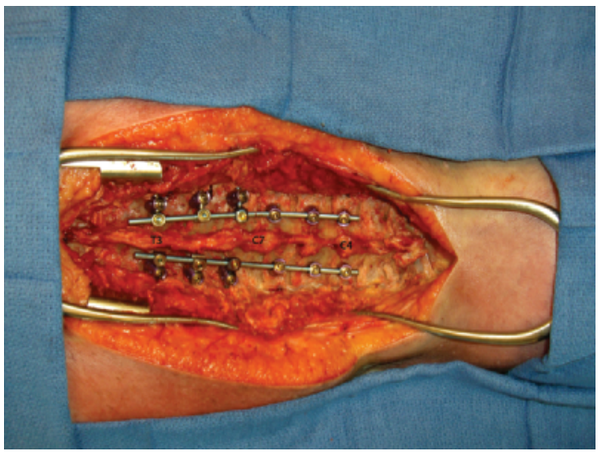


FIGURE 5-3

Instrumentation is placed above and below the C7 vertebra with a provisional rod. Note that off-set connectors are used in the thoracic spine from T1 to T3.

of the respective pedicle. It is crucial to remove any overhanging bone whether from residual facet overhang or lamina to prevent impingement of the neurologic structures during closure of the osteotomy. At this juncture, the spinal cord, C7, and C8 nerve roots should be fully visible and the C7 pedicle between the roots (Fig. 5-4). Hemostasis is maintained with Gelfoam thrombin and Floseal (Baxter Healthcare Corp.)

Decancellation of the C7 vertebral body is then begun. Several methods can be employed to perform the removal of bone from the vertebral body. The pedicle walls should be left intact if possible during this process to aid with protection of the neurologic structures. One method is use of a high-speed burr to thin the bone within the pedicle and subsequently remove the cancellous bone within the vertebral body. A second method is the use of successively larger taps, passing through the pedicles and into the vertebral body. Various forward and backward angle curettes also can assist with bone removal. Whether using the burr or taps, a wedge cavity is created via access through both pedicles such that only a cortical shell of bone remains. It is imperative that a uniform area of bone be resected to allow a symmetric closure of the osteotomy. A Penfield elevator is then used to expose the lateral walls of the vertebral body and a V-shaped area of bone is resected (Fig. 5-5). The resection is carried to the anterior cortex of the body. This is done with a narrow Leksell rongeur. The final area of bone to be removed is the posterior cortex and any remaining aspect of the C7 pedicle wall. This is done with a backward angle curette and should occur with relative ease if decancellation was done properly. The posterior cortex is carefully pushed downward into the wedge cavity, taking care not to retract the cord.

Stage IV—Correction of the Deformity

Once the osteotomy is complete, an unscrubbed assistant loosens the Mayfield attachment and gently elevates the patient's head. The surgeon helps to guide the head and closure of the osteotomy under direct visualization. Within the wound, close attention is paid to the exiting C7 and C8 nerve

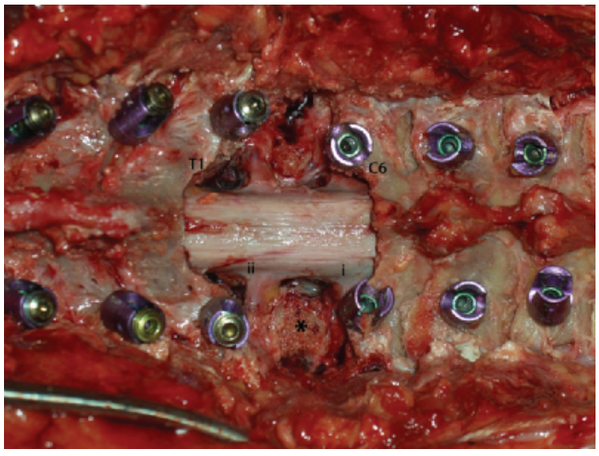


FIGURE 5-4

Complete removal of the C7 posterior elements has been performed. The caudal aspect of C6 has been removed as well as the inferior facets of C6 bilaterally. The cephalad aspect of T1 has been removed as well as the superior facets of T1 bilaterally. (Note the provisional rods have been removed for visualization purposes.) *, C7 pedicle; *i,* C7 nerve root; *ii,* C8 nerve root.

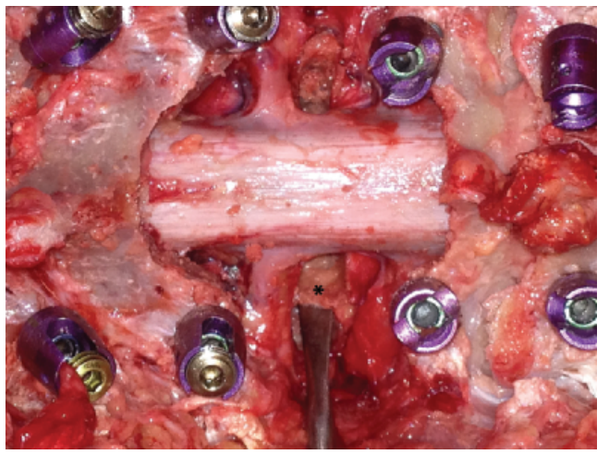
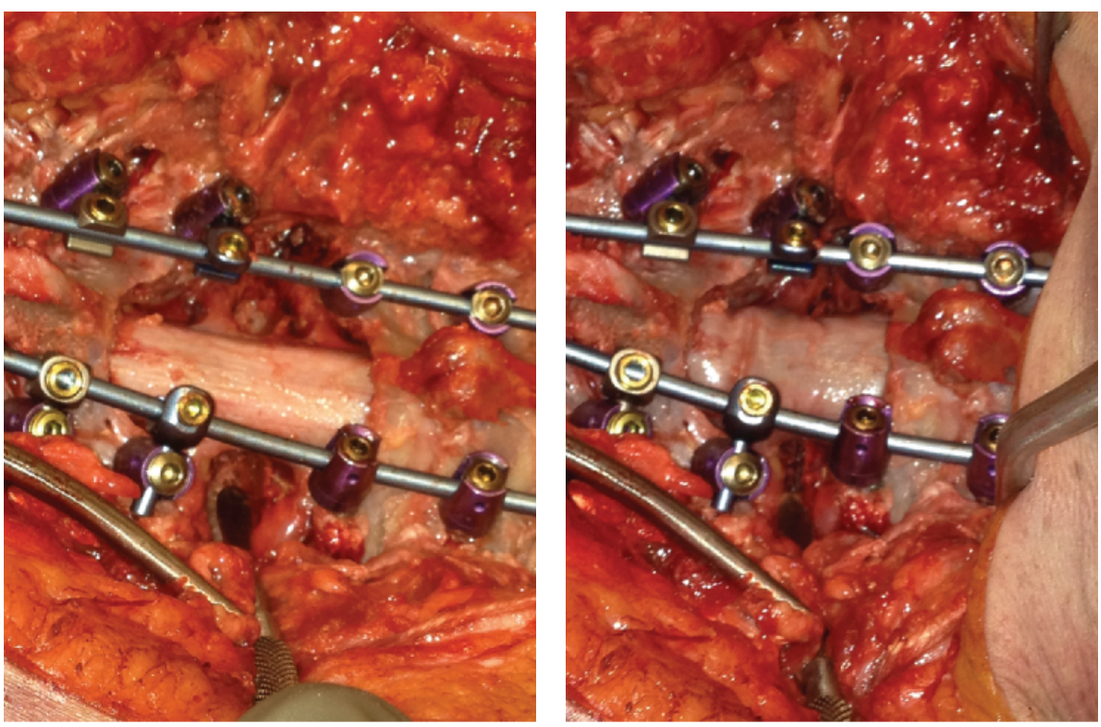


FIGURE 5-5
Note the Penfield 4 retractor lateral to the *decancellated C7 pedicle wall.

roots as well as the spinal cord and buckling dura (Fig. 5-6). If there is any impingement evident during closure of the osteotomy, or neuromonitoring signals change, the osteotomy should be gently reversed and the offending agent (i.e., bone) should be resected. The lamina may need to be undercut or further facet resection may be necessary. After the osteotomy is closed the provisional rods should be locked in place and the Mayfield attachment secured to the table again. Assessment of the ~~CBV~~ should be done at this time to assure that adequate correction has occurred. It is important not Q1 to overcorrect the deformity. The overall alignment is assessed via fluoroscopy imaging as well as gross examination of the patient's head in relation to the torso. We then proceed to replace the provisional rods with the appropriate length permanent titanium rods. The final set screws are secured and finally tightened with the torque wrench.



A B

FIGURE 5-6
A,B: Note the Penfield 4 retractor within the osteotomy defect and the change in rod length and buckling of the dura following closure. The Penfield 4 retractor is no longer able to fit within the defect following closure of the osteotomy.

Stage V—Bone Grafting and Wound Closure

The wound should be copiously irrigated with normal saline. Decortication is performed at each facet joint and across each lamina within the fusion region using the high-speed burr. Local autograft is then placed along the decorticated regions. If additional graft is needed, iliac crest bone can be harvested. The wound is then closed in a layered fashion. A meticulous layered closure should be done to ensure proper healing occurs. It is especially critical that the fascial layer be reapproximated, as this layer tends to retract throughout the case, and if not careful can be missed. Poor wound closure can result in numerous complications including infection, fascial and/or wound dehiscence, hematoma, and poor cosmesis.

MIDCERVICAL EXTENSION OSTEOTOMY

Stage I—Anterior Release and Osteotomy

After induction of anesthesia, a Foley catheter, sequential compression stockings, and pneumatic compression devices are applied. Baseline readings of SSEPs and MEPs are obtained before positioning the patient. The preoperative x-ray with the operative plan is hung in the operating room for all physicians and assistants to reference.

The patient is positioned supine on the operating table with the head on a foam headrest, elevated with blankets and pillows to adjust for the kyphotic deformity. If there is a significant submandibular pannus, the soft tissue is retracted with wide tape to allow for greater access to the anterior cervical region. The shoulders are pulled caudally with tape. Rarely, the chin-on-chest deformity is so severe that the surgeon cannot access the anterior neck, and the procedure is abandoned. Patients with such severe kyphotic angulation may benefit from a trial of cervical traction.

We prefer to perform the anterior cervical approach through a transverse right side incision when above C7/T1. For illustrative purposes, we discuss the treatment of a C5/C6 kyphotic deformity for the remainder of this chapter.

After the standard Smith-Robinson anterior cervical exposure is performed, we place distraction pins into the bodies of C5 and C6 and then obtain a localizing x-ray to confirm the level. The pins are placed perpendicular to the longitudinal axis of the vertebral bodies in order to help with orientation during the anterior resection. It is sometimes difficult to confirm levels in patients with AS because the disc spaces are fused. In these patients, the surgeon may confirm levels by counting the spinous processes, looking for the angulation in the cervical spine, or by assessing the location of the deformity in relation to the hyoid bone.

Following localization of the appropriate level, a generous discectomy is performed. If the disc space is completely fused, then a power drill may be used. The posterior endplates of C5 and C6 and all posterior vertebral osteophytes are removed. The posterior aspect of the disc space is "trumpeted" by undercutting the posterior body walls of C5 and C6.

After the generous wedge is created at C5/6, a left C6 pediculectomy is performed. The left C6 pedicle is accessible from a right-sided anterior cervical approach because the surgeon is looking across midline and can visualize the contralateral pedicle. The ipsilateral pedicle is difficult to visualize from the anterior approach, and the right pediculectomy will need to be completed during the posterior stage of the operation.

Subsequent to the pediculectomy, bilateral C6 foramen transversaria are exposed. The longus colli muscles are reflected at the cephalad aspect of the C6 body bilaterally, out to the edge of the foramen. The anterior portions of the foramen are then removed (Fig. 5-7). This is done to prevent

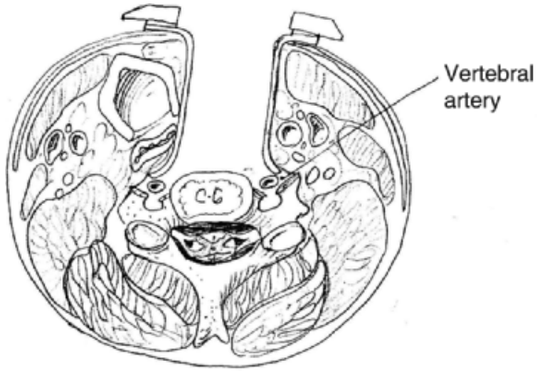


FIGURE 5-7

Note removal of the anterior portions of the foramen transversaria.

kinking of the vertebral arteries during the upcoming reduction maneuver. At the completion of the first stage, close the anterior cervical incision with staples only, and apply a sterile dressing. We anticipate coming back to the anterior approach in stage six, so a typical layered closure is delayed.

Stage II—Posterior Exposure and Instrumentation

The patient is placed in Mayfield pins while in the supine position. We attempt to place a rigid cervical collar (occasionally, this is not possible due to the chin-on-chest position), and then carefully flip the patient prone onto another operating table. The prone setup is exactly as described previously for the pedicle subtraction osteotomy (PSO).

The exposure of the posterior elements and insertion of hardware is virtually identical to that described previously for the PSO, with the exception of vertebral levels. Anchors are placed three levels above and three levels below the deformity. Consequently, for a C5–C6 deformity, we place lateral mass screws at C3–C5 and pedicle screws at C7–T2.

Stage III—Osteotomy

The osteotomy begins with removal of the inferior half of the C5 spinous process and lamina (if this bone is not removed, it will impinge on the posterior dura when the correction is performed). The inferior articular process of C5 is removed below the C5 lateral mass screw. All of the posterior elements of C6 are removed including the spinous process, lamina, superior articular process, inferior articular process, and the residual C6 pedicles (the portion of the C6 pedicles that was not removed during the anterior approach). Use of a high-speed burr, fine curettes, and rongeurs allows efficient removal of bone. The exiting C6 and C7 nerve roots are completely exposed when the resection is complete. Removal of the posterior portion of the foramen transverium completes the bilateral foramen transversectomies at C6. This step is necessary to prevent kinking of the vertebral artery during correction. There is often abundant venous bleeding from the periarterial venous plexus, and this can be controlled with thrombin-soaked Gelfoam and/or Floseal (Baxter Healthcare Corp.). Finally, the cephalad half of the spinous process and lamina, and the superior articular facet of C7 are removed (also to prevent impingement of the posterior dura during correction). Prior to correction, the exposure and bone resection should look very similar to that described in the PSO section and seen in Figures 5-4 to 5-6.

Stage IV—Correction of Deformity

The deformity is corrected in the same manner as described previously for the PSO.

Stage V—Bone Grafting and Closure

The fusion area is prepared and wound closed in the same manner as described previously for the PSO.

Stage VI—Anterior Instrumentation

The patient is positioned supine again onto a separate operating table. After repositioning, evoked potentials are assessed. The head is placed on a foam cushion and the Mayfield attachment removed. The prior anterior incision is prepped and the skin staples removed.

The anterior exposure is redeveloped. The distraction pins are placed again into the vertebral bodies of C5 and C6, and mild distraction is applied. A tricortical iliac crest autograft is measured, cut to size, and inserted into the now parallel interbody space at C5–C6. The distraction pins are removed, and an appropriate-size anterior cervical plate is applied (Fig. 5-8).

The platysma is then reapproximated, and the anterior skin incision is closed with a subcuticular suture. A rigid collar is applied.

POSTOPERATIVE MANAGEMENT

The patient remains intubated and is taken to the recovery room. Postoperatively, the patient is allowed to temporarily emerge from the anesthetic in order to perform a neurologic exam. The patient is extubated after the anesthesiologist assesses airway edema with a leak test. Progressive ambulation is initiated immediately, and the cervical hard collar is kept in place for 6 weeks.

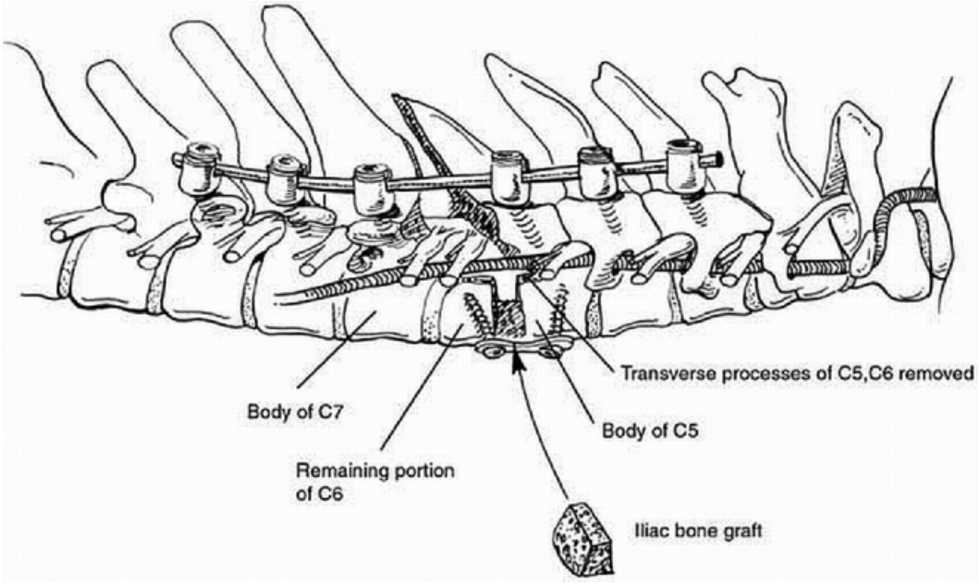


FIGURE 5-8
Final construct with kyphotic reduction.

CONCLUSION

Q2 Patients with chin-on-chest deformity pose an anesthetic and surgical challenge. Modern anesthetic and surgical techniques allow for a relatively safe correction of this deformity (Fig. 5-9). Provisional rods ~~used system~~ allow for controlled reduction of the deformity after the osteotomy has been performed. Our techniques are not the only methods of achieving reduction of this deformity; however we have used them with success on a number of cases. The potential complications of this procedure include all of those relevant to cervical spine surgery including dysphagia, infection, radiculopathy, pseudarthrosis, loss of sagittal correction, spinal cord injury, and anesthetic risks.

A B

FIGURE 5-9
A: Preoperative.
B: Postoperative.

RECOMMENDED READING

1. Belanger TA, Milam RA, Roh JS, et al.: Cervicothoracic extension osteotomy for chin-on-chest deformity in ankylosing spondylitis. *J Bone Joint Surg Am* 87: 1732–1738, 2005.
2. LaChapelle EH: Osteotomy of the lumbar spine for correction of kyphosis in a case of ankylosing spondylitis. *J Bone Joint Surg Am* 28: 851–858, 1946.
3. Mason C, Cozen L, Adelstein L: Surgical correction of flexion deformity of the cervical spine. *Calif Med* 79: 244–246, 1953.
4. Mehdian S, Arun R: A safe controlled instrumented reduction technique for cervical osteotomy in ankylosing spondylitis. *Spine* 36: 715–720, 2011.
5. Ondra SL, Marzouk S, Koski T, et al.: Mathematical calculation of pedicle subtraction osteotomy size to allow precision correction of fixed sagittal deformity. *Spine* 31: E973–E979, 2006.
6. Simmons EH: The surgical correction of flexion deformity of the cervical spine in ankylosing spondylitis. *Clin Orthop* 86: 132–143, 1972.
7. Smith-Petersen MN, Larson CB, Aufranc OE: Osteotomy of the spine for correction of flexion deformity in rheumatoid arthritis. *J Bone Joint Surg Am* 27: 1–11, 1945.
8. Urist MR: Osteotomy of the cervical spine: report of a case of ankylosing spondylitis. *J Bone Joint Surg Am* 40: 833–843, 1958.

Queries

[Q1] Please provide expansion for "CBV" if appropriate.

[Q2] Please check the first part of the sentence beginning "Provisional rods used system allow…" for sense.

[Q3] Please check the phrase "the out" in the sentence beginning "Complete exposure is performed…" for sense.