

# Anterior cervical osteotomy: operative technique

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Received: 26 March 2017 / Revised: 30 April 2017 / Accepted: 28 May 2017 / Published online: 7 June 2017  
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## Abstract

**Purpose** Correction of rigid cervical deformities often requires osteotomies to realign the spine. Cervical pedicle subtraction osteotomy can be technically challenging due to the presence of cervical nerve roots and usually can only be performed at C7 or T1 due to the presence of vertebral arteries. In contrast, anterior cervical osteotomy can be performed throughout the cervical spine and is a safe and effective method for correction of both sagittal and coronal cervical deformities. We describe the anterior cervical osteotomy technique with a review of the pertinent literature.

**Methods** A step-by-step technical guide for anterior cervical osteotomy is provided with a focus on surgical nuances and complication avoidance. Two illustrative cases of fixed sagittal and coronal deformities are included to demonstrate the substantial amount of deformity correction achievable using the anterior cervical osteotomy technique.

**Results** Both patients in the illustrative cases had successful clinical and radiographic outcome following deformity correction utilizing the anterior cervical osteotomy technique.

**Conclusion** Anterior cervical osteotomy is a safe and effective technique for correction of rigid cervical deformities. Spine surgeons should be familiar with this technique to optimize clinical outcome in patients undergoing cervical deformity correction.

**Keywords** Cervical deformity · Anterior osteotomy

## Introduction

Patients with cervical spine deformity can present with pain, myelopathy, sensorimotor deficits, as well as inability to maintain horizontal gaze. Flexible cervical deformities often can be corrected with various surgical techniques such as multi-level anterior cervical discectomy and fusion (ACDF), cervical corpectomy (CC), posterior cervical instrumentation and fusion, or a combination of these procedures. However, rigid cervical spine deformities may require osteotomies to realign the spine and to achieve adequate deformity correction. Pedicle subtraction osteotomy (PSO) in the cervical spine can be challenging due to the presence of cervical nerve roots and the potential risk causing impaired hand function. In addition, PSO is usually only feasible at C7 or T1 due to the presence of vertebral arteries in the transverse foramen.

Anterior cervical osteotomy (ACO), defined as an osteotomy through the uncovertebral joints and extending next to the transverse foramen bilaterally, is another powerful technique that can provide significant kyphosis correction in rigid cervical deformities. It is important to understand that the ACO technique requires motion through the facet joints posteriorly to gain kyphosis correction. Therefore, it must be performed in conjunction with a posterior facet release if the posterior elements are fused. Furthermore, in patients with fixed coronal deformities, asymmetrical osteotomy can be utilized to gain substantial correction in the coronal plane.

We provide a step-by-step technique guide with two illustrative cases with a discussion of surgical nuances and a review of the pertinent literature.

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## General considerations

Prior to surgery, the vocal cord function should be assessed by an otolaryngologist in patients with previous anterior cervical spine surgeries. If the vocal cord function is normal, a left sided approach is generally preferred due to the longer course of the recurrence laryngeal nerve and the theoretically lower risk of iatrogenic recurrence laryngeal nerve injury. If the vocal cord function is impaired from a prior surgery, then the approach should be performed from the ipsilateral side of the injury to avoid potential bilateral vocal cord paralysis. Furthermore, if there is significant concomitant coronal deformity, approaching from the convex side is generally easier than approaching from the concave side.

During the initial positioning, the patient's head is often suspended in the air if a severe rigid kyphotic cervical deformity is present. In this situation, folded sheets along with a small gel or foam donut can help to support the head at the beginning of the case. Exposing the apex of the kyphotic deformity can also be challenging because of its depth in the wound. Gentle cervical traction with Gardner–Wells tongs (~15 lbs) can be applied to facilitate both intubation and initial approach to the anterior cervical spine. In patients with evidence of cervical cord compression, the mean arterial pressure (MAP) should be maintained above 80 mmHg during intubation and throughout the procedure to ensure adequate spinal cord perfusion.

The superior and inferior thyroid arteries may be encountered during exposure and can be safely ligated and divided to allow maximal surgical exposure. It is important to carefully isolate the superior thyroid artery prior to dividing it to minimize the potential of injuring the external branch of the superior laryngeal nerve, which can affect the pitch of voice if injured. The internal branch of the superior laryngeal nerve is larger and provides bilateral sensory innervation of the laryngeal mucosa, often accompanied by the superior laryngeal artery.

In addition, a detailed examination of both vertebral arteries on the pre-operative imaging studies is mandatory. The soft tissue dissection and osteotomy during an ACO extend lateral to the uncinatate joints and any aberrant course for the vertebral arteries must be noted to minimize the risk of inadvertent vertebral artery injuries.

## Surgical technique

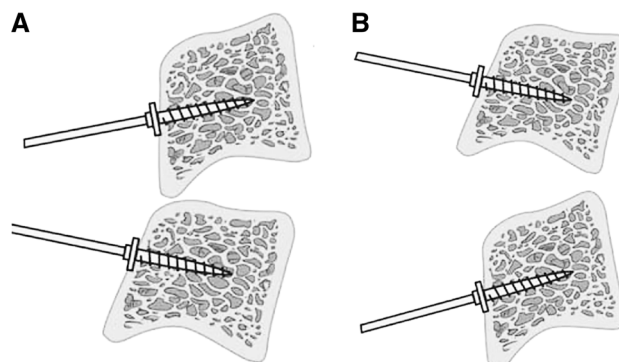
The patient is brought into the operating room and placed supine on the operating table. After general endotracheal anesthesia, the neck is prepped and draped in the usual fashion. A standard Smith–Robinson approach was used to expose the anterior cervical spine at the intended levels.

Fluoroscopy is used to confirm the levels. The longus colli muscles are then detached from their insertions at mid-vertebrae bilaterally using a bipolar cautery and retracted laterally using table-mounted retractors.

A Penfield dissector (#4 or #2) can be used for blunt dissection lateral to the uncinate. The costal process, which is the anterior ring of the foramen transversarium, can be used as an anatomic landmark to identify the uncinate at the level of the fused disc space. The disc space and the uncinatate joint are just medial to the cranial border of the costal process. Caspar pins can then be placed within the kyphotic segments above and below the level of where the osteotomy is desired. Two sets of pins can be used in osteoporotic patients for additional bony purchase. The pins are placed perpendicular to the anterior plane of the deformed cervical spine, which results in divergent pins alignment in a kyphotic spine. Pin placement in this manner can help to produce lordosis with pin distraction after the osteotomy is performed (Fig. 1).

Once the area of osteotomy is identified, the bony resection is initiated with a high-speed 3-mm matchstick burr. The morphology of the resection is dependent on the type of deformity. For purely kyphotic deformities, care must be taken to perform the resection perpendicular to the cervical spine and as much as possible in the same space as the former disc space to prevent an iatrogenic coronal plane deformity. For mixed coronal and kyphotic deformities, the bony resection can be made asymmetrically to facilitate proper alignment in the coronal plane. The bony resection is taken all the way posteriorly to the level of the posterior longitudinal ligament.

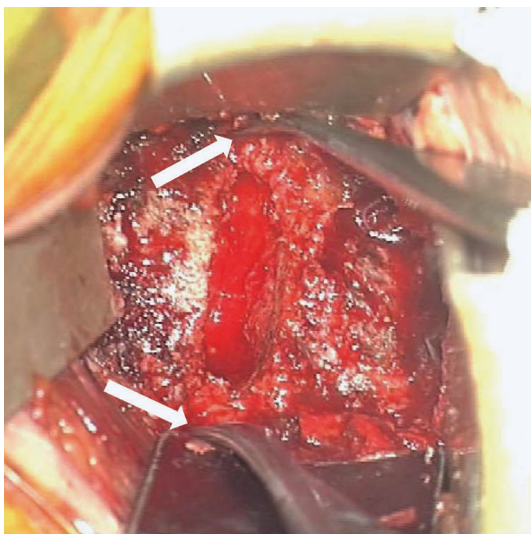
The lateral aspect of the bony resection should always be performed with extreme caution because iatrogenic vertebral artery is possible during this step. To prevent this complication, the vertebral artery is protected using a



**Fig. 1** **a** The Caspar pins are placed perpendicular to the anterior plane of the kyphotic cervical spine, which results in divergent pins alignment initially; **b** distraction of Caspar pins after completion of osteotomy maximizes the amount of lordosis obtained through the osteotomy

Penfield #4 or #2 during the lateral bony resection (Fig. 2). The Penfield identifies the lateral border of the uncinata where the vertebral artery resides. Once the bone is resected to this border, the remaining thin shell of the bone can be removed with a micro-curette. A foraminotomy is recommended at the levels where the bony resection is performed to prevent nerve root compression during neck extension.

To correct the deformity, the sheets under the head are removed one at a time by the anesthesia team while gentle downward force is applied on the forehead through the sterile drapes by the surgeon. Simultaneously, the Caspar pins are distracted to facilitate kyphosis correction. To distract the disc space, one can also rotate a Cobb elevator within the osteotomy site to separate the bony edges while simultaneously distracting along the Caspar pins. In addition, one can use a vertebral body spreader (Fig. 3). Alternatively, using sequentially larger disc space sizers can also help to open up the disc space. In the senior author's experience, pushing on the forehead is the safest and the least likely to result in cutout of the pins or fracture of the vertebral body during kyphosis correction (Fig. 4a). Even in cases where there is a posterior fusion with instrumentation, one can usually get a partial correction of the deformity with this maneuver. This is because the force of pushing on the forehead uses a long lever arm such that, after anterior osteotomy, most rods will flex into less kyphosis. Once the correction of kyphosis gets to the point where the occiput touches the operating table, the correction is complete. If the correction is still inadequate, the anesthesiologist can place a rolled sheet under the shoulders to further lordose the cervical spine. The weight on the



**Fig. 2** An intraoperative photograph demonstrating the vertebral artery is protected using a Penfield #2 dissector during resection of the uncinates

Gardner–Wells tongs is increased ( $\sim 25$  lbs) to maintain the correction if needed.

Next, the distracted osteotomy space is filled with graft. Often, the bone edges of the osteotomy site are cancellous bone or fusion mass bone that can make the bone graft prone to subsidence. Therefore, the largest size bone graft is placed into the area of bony resection in both the cranial caudal dimension as well as the medial lateral dimension to provide the largest surface area possible for endplate support. If the deformity has been completely corrected, an anterior cervical plate with fixed angle screws is placed at the cranial and caudal levels. If the correction is inadequate and further posterior correction is necessary, then we place a trapezoidal-shaped graft that contacts the anterior part of the osteotomy site but not the posterior aspect, such that further lordosis can be achieved with posterior correction.

A buttress plate or an interference screw can also be used to prevent graft extrusion during the posterior operation when the patient is in the prone position (Fig. 4b). It is rare for us to not do posterior augmentation for an anterior osteotomy, since the endplates are soft cancellous bone. If immediate posterior fixation is not possible for any reason, a halo or a rigid brace is recommended, followed by posterior surgery when it is possible. Posterior fixation or significant external mobilization is always wise when correcting significant cervical deformities.

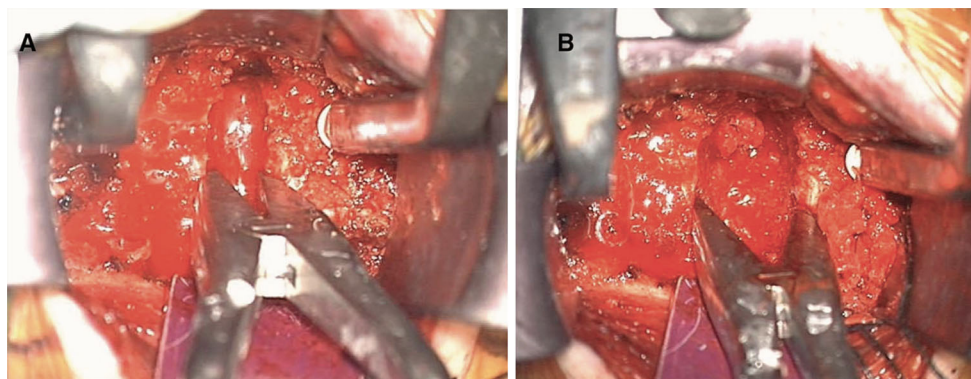
## Illustrative cases

### Case 1: fixed kyphotic deformity

A 20-year-old man with achondroplasia and multiple surgeries in the past including suboccipital craniectomy with C1–2 laminectomies, and spinal fusion from C5 to L4 presented with progressive myelopathy and right upper extremity weakness. Physical examination was remarkable for diffusely weakness in the right upper extremity (4/5), and myelopathic signs including hyperreflexia, positive Hoffmann's reflex, clonus, and unsteady gait. Cervical spine imaging reviewed a fixed cervical deformity and cervical stenosis and anterior cord compression at C2–3 and C3–4 (Figs. 5, 6). The C2–7 kyphosis was  $36.1^\circ$  with a C2–7 sagittal vertical axis (SVA) of 37.2 mm. Since the kyphotic deformity was rigid on flexion/extension X-rays (Fig. 5), anterior cervical osteotomies were planned at C2–3, C3–4 along with C4–5 ACDF for kyphotic deformity correction, augmented by posterior cervical decompression, instrumentation and fusion from C2 to C5 with connection to the prior posterior spinal instrumentations.

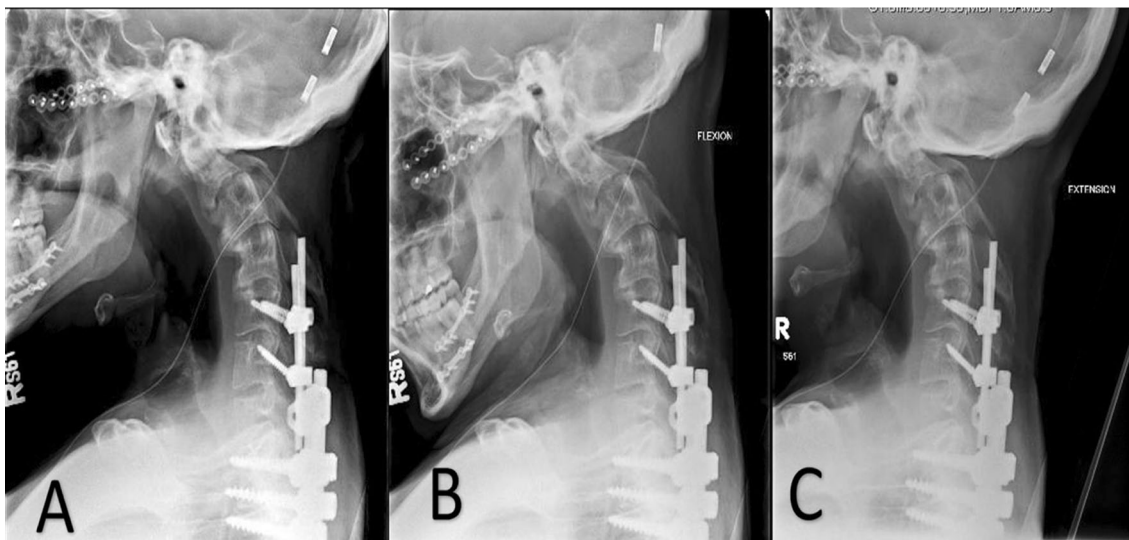
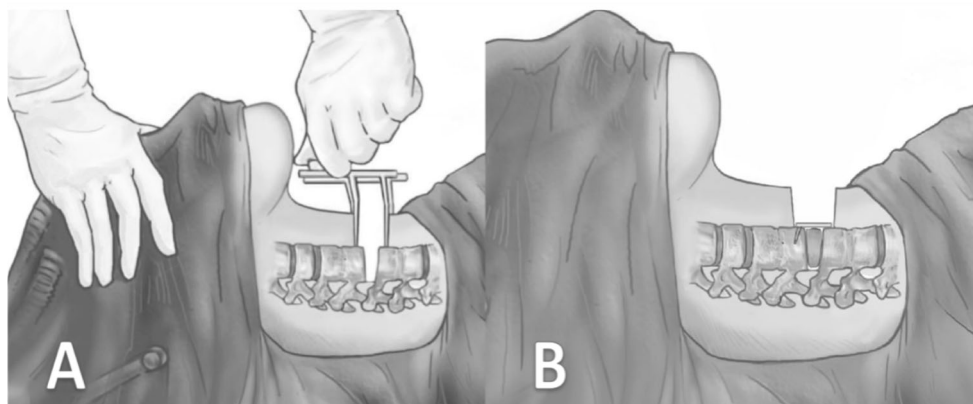
The patient tolerated the procedure well with stable neurological exam post-operatively. Follow-up cervical X-rays demonstrated excellent kyphosis correction





**Fig. 3** An intraoperative photograph demonstrating **a** inserting a vertebral body spreader into the disc space and **b** distracting open the disc space

**Fig. 4 a** An illustration showing correction cervical kyphosis by pushing down on the forehead taking advantage of large moment provided by the long lever arm while simultaneously distracting the osteotomy site using Caspar pins; **b** a buttress plate is placed to prevent graft extrusion in the prone position during the posterior part of the procedure

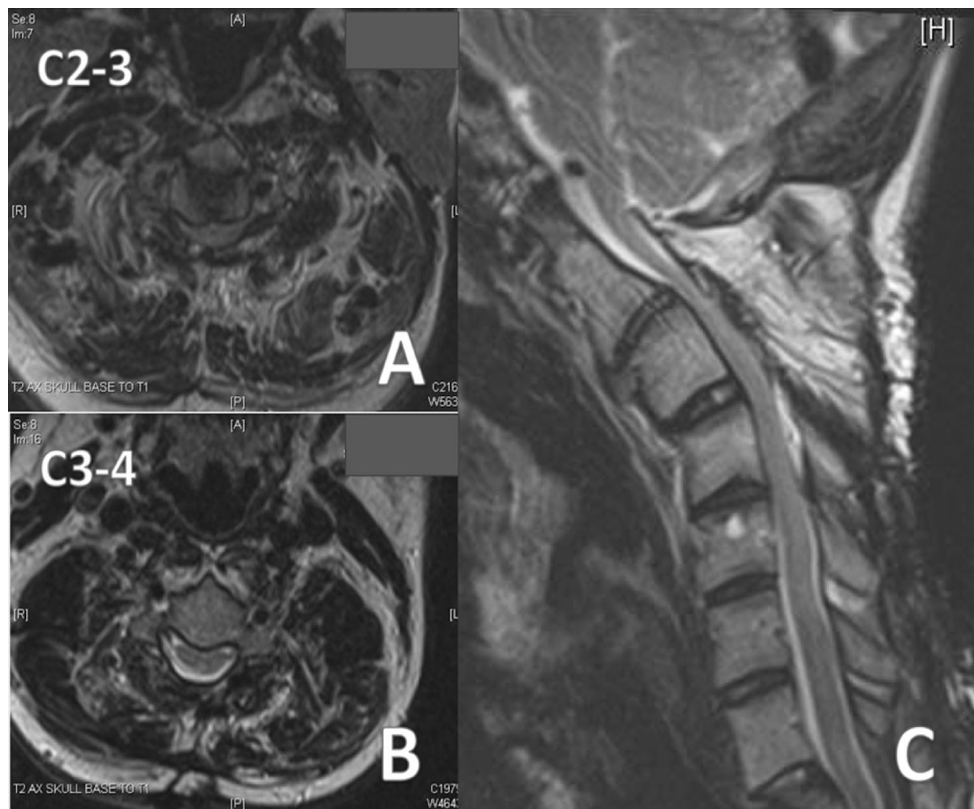


**Fig. 5** Pre-operative cervical X-rays in **a** neutral position, **b** flexion and **c** extension demonstrating a rigid kyphotic deformity with the presence of extensive anterior osteophytes at C2–3, C3–4 and C4–5

with a post-operative C2–7 lordosis of  $18.8^\circ$ , which equated to a  $54.9^\circ$  increase in cervical lordosis (Fig. 7). The C2–7 SVA improved from 37.2 to 0 mm post-operatively. The patient remained neurologically stable at the 10-month follow-up visit.

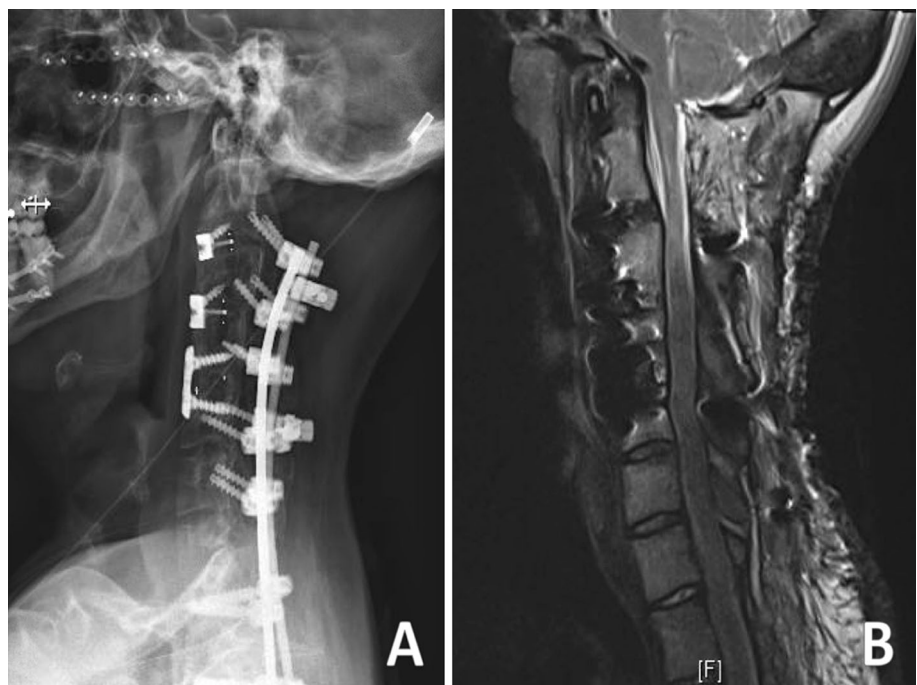
### Case 2: mixed coronal and sagittal deformity

A 56-year-old man presented with long-standing right side “ear-on-shoulder” deformity (Fig. 8). On physical examination, the patient was unable to erect his neck off the right



**Fig. 6** Pre-operative cervical spine MRI (T2WI) demonstrating severe spinal cord compression at **a** C2–3 and **b** C3–4; **c** the spinal cord appearing “draped” over the kyphotic cervical spine with diffuse anterior compression

**Fig. 7** Post-operative **a** lateral cervical X-ray and **b** MRI demonstrating excellent correction of the fixed cervical kyphotic deformity and circumferential decompression of the spinal cord at C2–3 and C3–4



**Fig. 8** Clinical photo demonstrating a severe “ear-on-shoulder” deformity



shoulder but otherwise unremarkable. Cervical X-rays reviewed a significant coronal deformity (Cobb angle from C2 to T2 = 50.2°) with poor sagittal alignment with a C2–7 SVA measuring 93.5 mm (Fig. 9). CT cervical spine demonstrated spontaneous circumferential fusion of the cervical vertebrae (Fig. 10). MRI cervical spine did not show any significant cervical stenosis.

Given the presence of spontaneous circumferential fusion, a combined anterior–posterior total subaxial reconstruction was deemed necessary. The patient first underwent ACOs at C3–4, C4–5, C5–6, and C6–7 for anterior release. Solitaire-C cage (Zimmer Biomet, Warsaw, IN, USA) was secured within each disc space with only a single screw to after osteotomy, which allowed some further lordosing the cervical spine after posterior release of the fused facet joints. The patient was then turned prone on to a Jackson frame, and the head was secured in Gardner–Wells tongs with bi-vector cervical traction. The posterior cervical spine was dissected subperiosteally and the fused facet joints were released with a high-speed burr at each level. The neck was extended further using bi-vector cervical traction after all the facet releases were completed to maximize cervical lordosis. Screw fixations were then placed from C2 to T3 in the standard fashion, followed by bilateral rod placement.

The patient tolerated the procedure well without complications. Post-operative X-rays demonstrated complete correction of coronal deformity (Fig. 11) and substantial improvement in cervical sagittal alignment (C2–7

SVA = 41 mm). The patient remained clinically well at follow-up (Fig. 12).

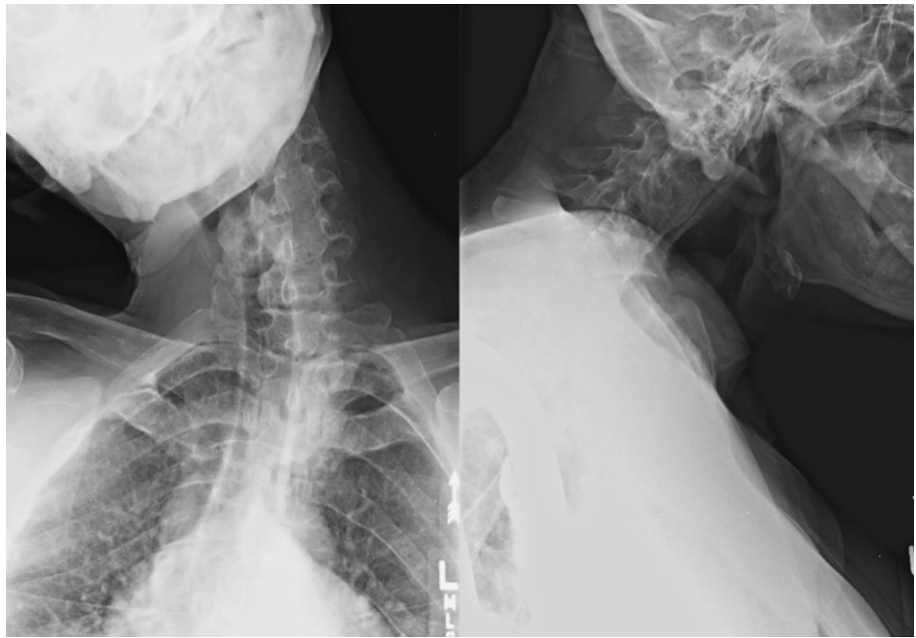
## Discussion

The goals for cervical deformity surgery include neural decompression, deformity correction, restoration of the horizontal gaze, as well as instrumentation and arthrodesis to maintain surgical correction. In general, a fixed deformity often requires osteotomy to realign the spine. Kandasamy et al. [5] and Nemani et al. [6] reviewed some general principles and various surgical techniques for cervical deformity correction.

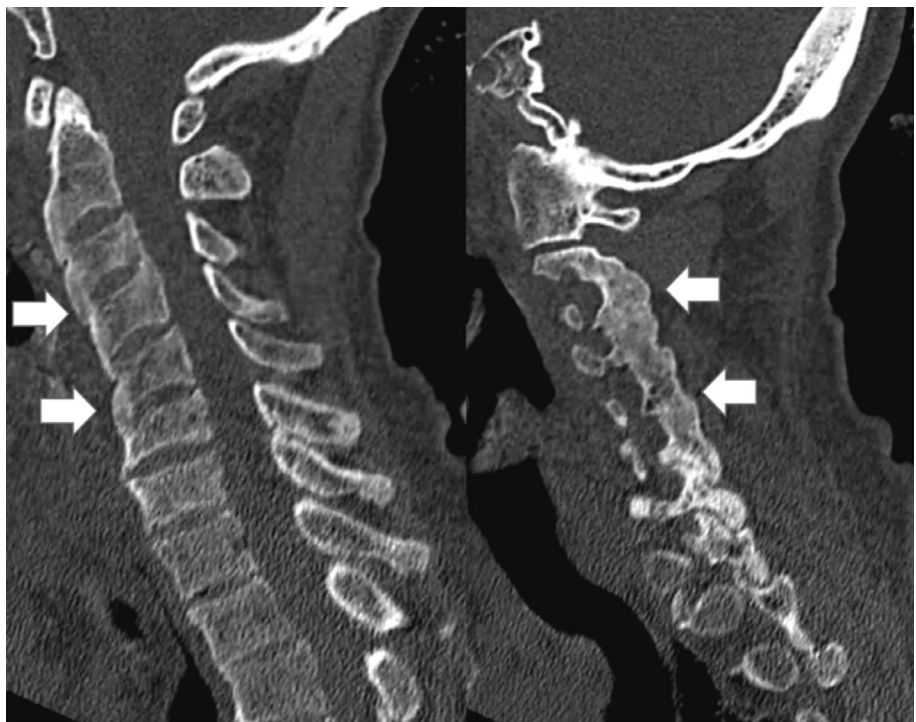
Posteriorly based osteotomy techniques can be challenging due to the complexity of the neurovascular structure in the cervicothoracic region. Smith et al. [7] reviewed a series of 23 patients who underwent posteriorly based three-column osteotomy (14 PSO and 9 VCR) for cervical deformity corrections and found a 56.5% complication rate including post-operative neurologic deficits, wound infection, distal junctional kyphosis and cardiorespiratory failure. Theologis et al. [3] reported using asymmetrical C7 PSO to treat a patient with coronal cervical deformity with fused facets at C6, C7 and T1 with favorable outcome. In addition, Cecchinato et al. [4] reported a series of 12 cases where posterior osteotomy techniques including Ponte osteotomy, PSO and VCR were successfully utilized to treat proximal junctional kyphosis in patients after long thoracolumbar spinal fusions.



**Fig. 9** Pre-operative cervical X-rays demonstrating a significant coronal deformity (Cobb angle from C2 to T2 =  $50.2^\circ$ ) with poor sagittal alignment (C2–7 SVA = 93.5 mm)



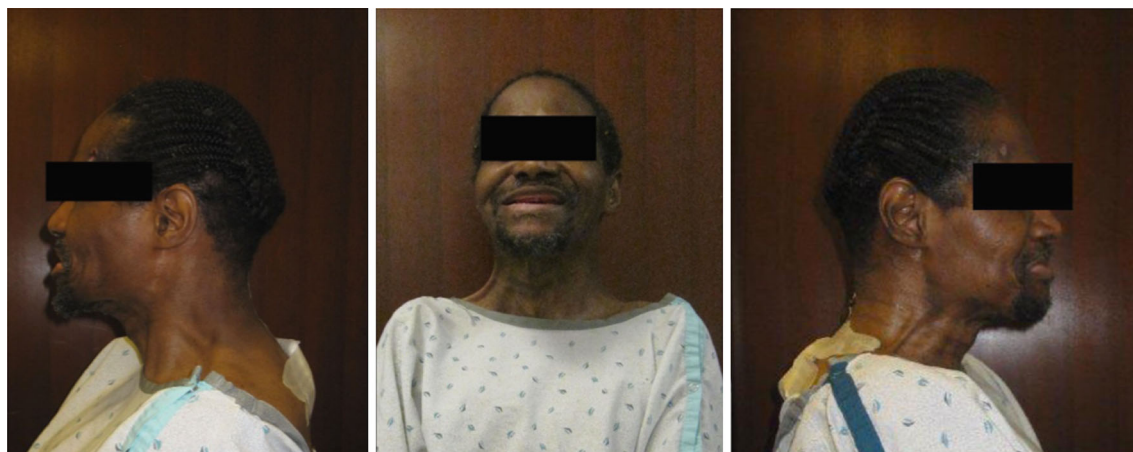
**Fig. 10** CT of the cervical spine demonstrating spontaneous circumferential fusion (arrows) of the cervical vertebrae



Anterior osteotomy is another powerful tool for correction of fixed cervical spine deformities. In 2014, Kim et al. [1] studied a series of 38 patients who underwent anterior osteotomy for rigid cervical deformity correction with an average follow-up of 3.4 years. They found that the mean angular correction for ATO was  $23^\circ$ , and the average angular correction increased to  $33^\circ$  if an

ATO was combined with an SPO. There were no neurological complications or intraoperative neuromonitoring changes in these patients. Another study by Kim et al. [2] examined the surgical outcome of 35 patients with cervical deformity and myelopathy. There were 31 patients who underwent ATO with or without posterior instrumentation, and 4 patients who underwent PSO.

**Fig. 11** Post-operative cervical X-rays demonstrating correction of fixed coronal deformity and improvement in sagittal alignment



**Fig. 12** Post-operative clinical demonstrated complete correction of cervical deformity

They found that the ATO group had a mean angular correction of  $27.7^\circ$  with a mean translational correction of 1.8 cm, whereas the PSO group had a mean angular correction of  $48.8^\circ$  with a mean translational correction of 2.8 cm.

In 2015, Kim et al. [8] compared the amount of kyphosis correction obtained via cervical SPO, PSO and ATO in a total of 61 patients. The mean angular corrections obtained for a single-level SPO, PSO and ATO were  $10.1^\circ$ ,  $34.5^\circ$  and  $17.1^\circ$ , respectively. In addition, the sagittal corrections for a single-level SPO, PSO and ATO measured by the basion plumb line were 3.5, 2.8 and 1.3, respectively. Combining ATO with SPO and posterior cervical fusion generated a mean angular correction of  $27.8^\circ$  per level, along with a sagittal correction of 3.6 cm. Therefore, a combined ATO with SPO provided equal or better

corrections than isolated PSOs, with equal operative times and less estimated blood loss (325 vs. 712 mL,  $P = 0.01$ ).

## Conclusion

Anterior osteotomy is a powerful but under-utilized tool for correction of fixed cervical spine deformities. Spine surgeons should be familiar with this technique as it can often provide adequate correction and avoid the need for a cervical PSO.

## Compliance with ethical standards

**Conflict of interest** Dr. Riew receives royalties from Biomet and Medtronic, receives grants from AOSpine, Cerapedics and Metronic, and receives honorarium from NASS and AOSpine. Dr. Tan has nothing to disclose.



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