Several surgical procedures have been attempted to treat fracture–subluxation occurring in the subaxial cervical spine, and the clinical outcomes of these operations have been reported. To the best of our knowledge, however, there are no reports in which authors have described treatment for cervical subluxation associated with an anomalous VA course in the subaxial cervical spine. In the present report, we describe the surgical treatment of a patient with a unilateral fracture–subluxation at the right C6–7 facet joint associated with right C-7 radiculopathy and an abnormal entrance level of the bilateral VAs into the transverse foramen. In this patient, surgical treatment was successfully performed using a cervical PS/rod system.

Case report

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The authors report the case of a 62-year-old woman who suffered an accidental fall and complained of severe neck pain and right C-7 radiculopathy. A right C6–7 facet fracture–subluxation was diagnosed. Bone fragments impinged on the right C-7 nerve root at the neural foramen. The bilateral vertebral arteries (VAs) ascended at the anterior aspect of C-6 and C-5 and entered the transverse foramen at the C-4 level.

Based on findings of anomalous VAs, the authors applied a pedicle screw (PS)/rod system to effect surgical correction of the deformity. Intraoperatively, they successfully performed reduction of the subluxation, decompression of the impinged nerve root, and minimum single-segment fusion involving the placement of a PS/rod system. After surgery, the patient's neurological deficit dramatically improved and spinal fusion was completed without any loss of deformity correction.

Prior to surgery for cervical injuries, the possible presence of an abnormal VA course should be considered. Preoperative detection of anomalous VAs will affect decisions on the appropriate corrective surgery option in cases of cervical spine injuries. (DOI: 10.3171/SPI-07/07/065)

Key words • cervical spine • pedicle screw • subluxation • vertebral artery anomaly

Abbreviations used in this paper: CSF = cerebrospinal fluid; CT = computed tomography; MR = magnetic resonance; PICA = posterior or inferior cerebellar artery; PS = pedicle screw; VA = vertebral artery.
7 facet joint had migrated to the right C6–7 foramen (Fig. 1C). A left parasagittal CT reconstruction showed normal structures of the left facet joints, indicating a unilateral C6–7 fracture–subluxation. Both T1- and T2-weighted midsagittal MR imaging revealed mild anterior and posterior compression of the C6–7 cord, but indication of traumatic disc herniation was absent.

An axial CT scan at the C-1 level showed that the size of the transverse foramen on the left side was smaller than that on the right side (Fig. 2). In addition, axial CT images of the subaxial cervical spine showed that the bilateral transverse foramina at C-5 and C-6 were smaller compared with those at C-3 and C-4 (Fig. 2). These CT findings indicated the presence of an abnormal course of bilateral VAs in the cervical spine. To analyze the VA anomalies, we first performed MR angiography but its findings were unclear because of the artifact caused by the patient’s false teeth. In addition, the precision of the CT scanner in our emergency center was insufficient to perform CT angiography. Thus, in the present case, we used conventional catheter angiography to evaluate the details of the VA anomalies.

Selective left VA angiograms demonstrated that the left VA ascended at the anterior aspect of the C-6 and C-5 vertebrae (Figs. 3A [arrowheads] and 4) and entered the transverse foramen at C-4 (Figs. 3A and B [arrows] and 4). In addition, the left VA did not run through the C-1 transverse foramen after emerging from the C-2 transverse foramen but, rather, entered the spinal canal at the caudal aspect of C-1 (Figs. 3A and B [double arrows] and 4), shifting directly to the left PICA (Fig. 3A and B [asterisks]). The right VA angiogram demonstrated that the right VA ascended at the anterior aspect of C-5 and C-6 (Figs. 3C [arrowheads] and 4) and entered the transverse foramen at C-4 (Figs. 3C and D [arrows] and 4), as was observed in the left VA. Regarding the upper cervical region, the course of the right VA was normal after emerging from the C-2 transverse foramen, entering into the spinal canal at the cranial aspect of C-1 (Figs. 3C and D [double arrows] and 4).

Preoperative Planning. Because fractured bone fragments were present within the neural foramen, we did not perform a closed reduction. We believed that the risk of the bone fragments’ impingement of the right C-7 nerve root would be reinforced at the time of reposition. Thus, we planned a surgical treatment that consisted of decompression of the impinged root, reduction of the subluxation, and spinal fusion.

Based on the radiological findings of the abnormal course of the bilateral VAs, we believed that there would be

Fig. 1. Preoperative imaging studies. A: Plain lateral radiograph showing anterior translation of the C-6 vertebra relative to the C-7 vertebra. B: Axial CT scan obtained at the C6–7 level demonstrating a fractured right facet joint (arrow) and bone fragments in the right neural foramen (arrowhead). C: Right parasagittal CT reconstruction revealing a fractured perched C6–7 facet joint (arrow) and bone fragments that migrated into the right C6–7 foramen (arrowhead).
an increased risk of VA injury when following an anterior approach to the C6–7 region because the VAs were unprotected by the transverse process. In contrast, the risk of VA injury due to PS insertion at C6–7 was decreased. Thus, we performed a one-stage posterior surgery that consisted of unroofing of the right C-7 nerve root, repositioning of the deformity, and spinal fusion in which a PS/rod system was placed.

**Operation.** The patient was placed prone. On exposing the C-6 and C-7 laminae and bilateral facet joints, we observed disruption of the C6–7 ligamentum flavum and joint capsule bilaterally. At this stage, we observed CSF leaking from the right C6–7 interlaminar space. The right C7 superior facet was fractured and translated posteriorly, forming the perched C6–7 facet on the right side. Segmental mobility at C6–7 was increased compared with the adjacent C5–6 and C7–T1 segments. We inserted PSs at C-6 and C-7 bilaterally. To improve the safety and accuracy of the screw insertion, we performed pedicle probing under lateral radiographic imaging. In addition, we used an angled device that had been developed in our laboratory (unpublished data). After insertion of the probe, we resected the caudal portion of the C-6 lamina, the cranial portion of the C-7 lamina, and the C6–7 facet on the right side. During this process, we found bone fragments compressing the lateral portion of the dura mater and the C-7 nerve root on the right side. After removal of the bone fragments, we found a small dural tear at the dura–nerve root sheath transitional region. We confirmed that CSF leaked through this tear.

After unroofing the right C-7 nerve root, we fixed 4.75-mm-diameter Isola rods to the screws on both sides. Tightening the locking nuts resulted in complete repositioning of the C6–7 subluxation. A strut was harvested from the left iliac crest and grafted onto both sides of the C6–7 spine process by using an interspinous process wiring technique. We placed a free fat graft on the dural tear and sprayed fibrin gel over the fat tissue to shield the right C6–7 space and prevent CSF leakage.

**Postoperative Course.** Postoperative cervical radiographs showed the PS/rod system had completely reduced the subluxation deformity (Fig. 5A). Axial CT scanning demonstrated proper positioning of the PSs (Fig. 5B) and extensive unroofing of the right C-7 nerve root (Fig. 5B arrow). On the day following surgery, the patient experienced relief of her neck pain. She gradually recovered muscle power in her right upper arm, which returned to normal 10 months after the surgery. Follow-up radiographs acquired 1 year after surgery demonstrated complete spinal fusion at C6–7 without any loss of spinal correction (Fig. 5A). At the final follow-up examination 2 years after surgery, the patient had no neurological deficits, did not suffer of any neck pain, and had no restriction in neck motion.

**Discussion**

Bruneau et al.4 analyzed the courses of VAs in the subaxial cervical spine in 250 patients and found that 93% of the arteries ran a normal course and entered the C-6 transverse foramen. In the other 7% the entrance level of the VA was abnormal as follows: at C-3 in 0.2%, C-4 in 1.0%, C-5 in 5%, and C-7 in 0.8% of cases. Thirty-one (12.4%) of the 250 patients harbored a unilateral anomaly of the VA entrance level, and only two patients (0.8%) had bilateral VA anomalies. In the present case, the bilateral VAs entered

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**Fig. 2.** Axial CT scans acquired at the C-1 (upper), C-4 (center), and C-5 (lower) levels showing that the size of the transverse foramen was smaller at C-1 on the left side (arrow) and at C-5 on both the left and right sides (arrowheads).
into the transverse foramen at the C-4 level, indicating a rare anatomical variation of the VA entrance level.

Tokuda et al. analyzed VA courses at the craniovertebral junction in 300 patients and reported two patients (0.67%) in whom the PICA originated from the VA between C-1 and C-2 and entered into the spinal canal from the caudal side of C-1. This was supplementarily examined by Sato et al., who found that the incidence of such VA anomalies was 0.36%. In the present case, the same type of VA anomaly described by Tokuda et al. was present in our patient on the left side. To the best of our knowledge, there have been no reports of cases in which different types of VA anomalies were simultaneously present at the craniovertebral junction and the subaxial cervical spine, as was observed in the present case.

For detecting VA anomalies, there have been several analytical methods including catheter-based angiography, MR angiography, and 3D CT angiography. Among these, MR angiography and 3D CT angiography are less invasive than catheter angiography. In addition, 3D CT angiography has the additional advantages that it can depict VA images more precisely and reconstruct the image from a voluntary direction, delineating the VA and the circumferential osseous tissue simultaneously. Despite these benefits of MR angiography and 3D CT angiography, we used catheter angiography in the present case because the MR angiograms were unclear due to artifact, and the precision of our CT scanner was insufficient to perform 3D CT angiography.

Previous reports of cases on the clinical outcome of radiculopathy associated with unilateral cervical spine injury in which radiculopathy persisted after treatment showed that persistence of radiculopathy was more frequent when the cervical injury was treated conservatively and/or the reduction of the displaced facet was insufficient. In the present case, impingement of the right C-7 nerve root was caused by bone fragments derived from the fractured facets. We recognized the importance of anatomical reduc-

Fig. 3. Lateral (A and C) and anteroposterior (B and D) angiograms with selective contrast of the left (A and B) and right (C and D) VAs. The left VA ascends at the anterior aspect of C-6 and C-5 (arrowheads, A) and enters the transverse foramen at C-4 (arrows, A and B). The left VA does not run through the C-1 transverse foramen after emerging from the C-2 transverse foramen but enters the spinal canal at the caudal aspect of C-1 (double arrows, A and B), shifting directly to the left PICA (asterisks, A and B). The right VA ascends at the anterior aspect of C-6 and C-5 (arrowheads, C) and enters the transverse foramen at C-4 (arrows, C and D). The right VA runs a normal course after emerging from the C-2 transverse foramen and enters into the spinal canal at the cranial aspect of C-1 (double arrows, C and D). The top portion of the image in A and the entirety of the images in B and C are subtraction images. In C and D, the right VA is not selectively contrasted, but other arteries, including the carotid artery, are contrasted simultaneously.

Fig. 4. Schematic drawings of the anomalous courses of bilateral VAs seen anteriorly (left) and posteriorly (right).
tion of the subluxation, appropriate decompression of the damaged nerve root, and stabilization of the injured segment of vertebrae.

The authors of previous reports have described using open reduction for unilateral cervical injury performed via anterior or posterior approaches.\(^3\)\(^,\)\(^9\)\(^,\)\(^13\) There have also been reports of intraoperative VA injury during anterior cervical fusion.\(^5\)\(^,\)\(^14\) In the present case, the bilateral VAs ascended at the anterior aspect of the vertebrae and remained unprotected by the transverse processes at the C5–7 levels. Thus, the risk of VA injury in anterior surgery would be much higher than that in cases of normal VA anatomy, and we decided that a posterior approach would be more appropriate in this case.

With regard to posterior surgeries for the reduction and stabilization of unilateral cervical injuries, other investigators have described the application of a lateral mass plate system,\(^9\)\(^,\)\(^13\) which provided satisfactory results in many of these cases; however, late-developing kyphosis occurred in some patients in whom lateral mass plate systems were used.\(^9\) During surgical planning in the present case, questions arose on whether fixation with lateral mass screws could stabilize the spine in minimum, single-segment (C6–7) surgery. In addition, our intention to unroof the right C-7 nerve root indicated that only a limited area would be available for the insertion of right C-6 lateral mass screws. In light of these treatment factors, we concluded that utilization of lateral mass screws for the anchors would have required us to perform no less than a two-level C5–7 fusion.

**Fig. 5.** Follow-up imaging studies. A: Plain lateral radiograph obtained 1 year after surgery showing complete reduction of the C6–7 subluxation and spinal fusion after application of the PS/rod system. B: Axial CT scans obtained at the C6 (upper), C6–7 (center), and C-7 (lower) levels taken 3 weeks after surgery demonstrating proper insertion and positioning of the PSs and extensive unroofing of the right C-7 nerve root (arrow).
Authors of biomechanical studies on the cervical spine have reported that PSs have greater resistance to pullout forces than lateral mass screws and are superior for the correction of cervical injury. The insertion of PSs at the C3–6 levels, however, poses a potential risk of VA injury that may result in serious complications. In the present case, the bilateral VAs did not run through the transverse foramina but were located at the anterior aspect of the C-6 vertebral body. Thus, the intraoperative risk of VA injury with the insertion of C-6 PSs was extremely low. When the superior, inferior, or medial wall of the pedicle is perforated by the screw, a risk of nerve root injury exists. Abumi et al. have reported that two of 669 cervical PSs caused nerve root injury, but other investigators have shown that the incidence of nerve root complication associated with lateral mass screws is not necessarily lower than that of PSs. We therefore decided to apply a PS fixation system containing a rigid constrained screw/rod connection. In using this system, we were able to execute a perfect anatomical reduction of the displaced cervical spine. Although extensive unroofing of the right C-7 nerve root was necessary, we achieved stabilization of the spine with minimum single-segment (C6–7) surgery.

Conclusions

Before undertaking surgery in cases of cervical spine injury, the possible presence of an anomalous VA course should be taken into account. A preoperative imaging demonstration of the detailed VA course will affect decisions regarding the appropriate surgical procedure for corrective surgery of cervical injuries.

References


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