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Supplemental material

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Supplemental Illustrative Cases

Case 1
A 50-year-old male presented for evaluation of a two-year history of neck pain with radiation to the right shoulder. He was full strength on physical examination without signs of myelopathy. MRI of his cervical spine revealed a small right C5-6 disc herniation with some collapse at the C5-6 disc space and mild right C6 foraminal stenosis. There was no facet degeneration at C5-6. Cervical flexion-extension x-rays demonstrated abnormal subluxation at C2-3, C3-4 and C4-5 disc spaces; however, no abnormal motion was seen at the C5-6 disc space.

CT spectroscopy was obtained to evaluate for a potential pain generator source. The scan revealed moderate increased uptake in the C5-C6 disc space consistent with a discogenic type of pain etiology (Supplemental Figure 1). CT of the cervical spine identified an enlarged and medially placed left C4 transverse foramen into the body of C4 (Supplemental Figure 2). Since this finding was not at the planned level of surgery, we elected to not obtain a pre-operative CT angiogram. As the patient is followed in the future for potential adjacent segment degeneration, anterior surgical intervention at C4/5 will have to take into consideration the abnormal anatomy of the left VA.

The patient underwent successful C5-6 total disc replacement and bilateral C6 foraminotomies without any complications (Supplemental Figure 3). He was discharged home on post-operative day two.

Case 2
A 55-year-old male with past medical history for C6-7 anterior cervical discectomy and fusion presented to an outside hospital after falling from a ladder while trimming a tree. CT cervical spine at the time of injury was significant for a comminuted C2 fracture with a vertically oriented fracture through the right side of C2 vertebral body that extended into the right C1-2 and C2-3 facets. There was also extension of this fracture into the right C2 transverse foramen. The fracture extended dorsally to the left C2 lamina and pars interarticularis as well. A type III odontoid fracture and diastasis of the bilateral C1-2 facets were also seen (Supplemental Figure 4). CT angiogram of the cervical spine showed occlusion of the right vertebral artery at the C2 level with reconstitution at the foramen magnum on the day of the injury. Unfortunately, the patient was discharged from the outside hospital in a cervical collar without being offered surgery for stabilization.

He continued to have persistent pain and presented to our hospital two weeks later. He had been told to remove the collar intermittently and perform gentle range of motion exercises so the collar immobilization had not been consistent. On physical examination, there was midline neck tenderness to palpation, 5/5 motor strength in all extremities, and no pathological reflexes. We elected to perform a cervical 1-4 posterior spinal fusion with use of intraoperative navigation. Given concern for vertebral artery injury, repeat CT angiogram was performed preoperatively and demonstrated progression of the right VA to complete occlusion in the foraminal segment and a dominant left VA with a V3 segment that was positioned low on the posterior aspect of the C1 posterior arch (Supplemental Figure 5). We planned for a C1-4 posterior instrumentation and
spinal fusion. During the operation, care was taken to meticulously dissect the posterior arch of C1 and avoid injuring the left vertebral artery. Additionally, a penfield-4 dissector was used to elevate the left VA superiorly to allow visualization of the entry point of the left C1 lateral mass screw and to protect against inadvertent arterial injury in case of skiving from the drill. A C1 bit was used to create the pilot hole for more precise technique after which the universal drill guide was used to drill to the appropriate depth. The surgery was successful without any complications, and the patient was discharged home on post-operative day three without signs of dysphagia or hoarseness (Supplemental Figure 6).

**Supplemental Figure 1.** Sagittal (A) and axial (B) CT Spectroscopy of the cervical spine following intravenous injection of 20 mCi of technetium 99m Medronate, revealing moderate increased radioisotope uptake in the C5-C6 intervertebral disc space.

**Supplemental Figure 2.** Coronal (A), sagittal (B), and axial (C) CT of the cervical spine demonstrating medially enlarged left C4 transverse foramen.

**Supplemental Figure 3.** Coronal (A) and sagittal (B) post-operative cervical x-ray following C5-6 total disc replacement and bilateral C6 foraminotomies.

**Supplemental Figure 4.** Sagittal (A), axial (B), and coronal (C) CT cervical spine demonstrating a right comminuted C2 vertebral body fracture, type III dens fracture, diastasis of the bilateral C1-2 facets, and acute fracture through the right C1-2 & C2-3 facet joints with extension into the C2 transverse foramen.

**Supplemental Figure 5.** CT angiogram of the cervical spine demonstrating a dominant left VA with a V3 segment that was positioned low on the posterior aspect of the C1 posterior arch.

**Supplemental Figure 6.** Coronal (A) and sagittal (B) post-operative cervical x-ray following C1-C4 posterior spinal instrumentation.