Adverse Events Associated With Anterior Cervical Spine Surgery

Abstract

Anterior cervical procedures for neurologic decompression and fusion, including cervical disectomy and cervical corpectomy, are commonly performed by orthopaedic surgeons and spinal neurosurgeons. These procedures are highly successful in treating most patients with persistent pain and neurologic symptoms that have not responded to nonsurgical methods. Adverse events occur infrequently, but several have been described, including esophageal injury, vertebral artery injury, dural tear, postoperative airway compromise, spinal cord injury, hematoma, dysphagia, dysphonia, and graft dislodgement. Newer procedures, such as cervical total disk replacement and the use of bone morphogenetic protein as a supplement to fusion, have raised unique concerns. Appropriate strategies must be utilized to avoid these adverse events, and the treating surgeon should have an understanding of how to detect and manage such events when they do arise.

Pain and neurologic symptoms secondary to pathology in the cervical spine are frequent clinical concerns. Most patients recover with nonsurgical interventions such as physical therapy, manipulation, nonsteroidal anti-inflammatory drugs, anesthetic and/or steroid injections, and activity modification. Surgical treatment is reserved for patients whose symptoms persist despite these interventions or who have significant or progressive neurologic dysfunction. Since the description of the anterior approach for cervical disectomy and fusion by Robinson and Smith1 in 1955, anterior cervical procedures have become some of the most common procedures performed by orthopaedic surgeons and spinal neurosurgeons. These procedures generally involve neurologic decompression done via disectomy and/or corpectomy, with fusion via structural bone graft or an interbody device, often augmented with an anterior cervical plate. Newer techniques, including cervical disk arthroplasty and the off-label use of bone morphogenetic protein [BMP] to supplement fusion, are also performed through an anterior approach.

The clinical success rate of these procedures is generally high, and adverse events are infrequent and manageable. However, awareness of potential adverse events is critical to reduce their incidence and to adequately inform patients regarding the surgical risk. As techniques and technologies continue to evolve, new adverse events become apparent.

For the purpose of this review, adverse events are defined as episodes that may affect patient outcome or that may require intervention, fur-
ther diagnostic tests, or monitoring. Studies examining adverse events are variable in nature, partially because assessment of surgical outcome and morbidity is often subjective. Thus, description and classification of adverse events may vary by surgeon, patient, or independent observer. Furthermore, individual adverse events can range in severity from mild and transient to severe and permanent, in some cases potentially leading to death.

The most common and potentially serious acute adverse events occurring in the intraoperative, early postoperative (within 1 week), and intermediate postoperative (1 to 6 weeks) periods include esophageal injury, vertebral artery injury, dural tear, spinal cord injury, peripheral nerve injury or radiculopathy.

Immediate to early postoperative (within 1 week)
- Airway compromise due to airway edema or hematoma
- Epidural hematoma
- Radiculopathy

Intermediate to longer term postoperative (1-6 weeks)
- Dysphagia
- Dysphonia
- Bone graft extrusion
- Wound infection

Immediate to early postoperative (within 1 week)
- Esophageal injury 0.2-0.4\(^2\)\(^-\)\(^4\)
- Vertebral artery injury 0.3\(^6\)
- Dural tear 3.7\(^6\)
- Spinal cord 0.2-0.9\(^3\)\(^6\)\(^7\)
- Peripheral nerve injury or radiculopathy 0.2-3.2\(^3\)\(^4\)\(^10\)

Table 1 Adverse Events Associated With Anterior Cervical Spine Surgery

<table>
<thead>
<tr>
<th>Adverse Event</th>
<th>Reported Incidence (%)</th>
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<tbody>
<tr>
<td>Esophageal injury</td>
<td>0.2-0.4(^2)(^-)(^4)</td>
</tr>
<tr>
<td>Vertebral artery injury</td>
<td>0.3(^6)</td>
</tr>
<tr>
<td>Dural tear</td>
<td>3.7(^6)</td>
</tr>
<tr>
<td>Spinal cord</td>
<td>0.2-0.9(^3)(^6)(^7)</td>
</tr>
<tr>
<td>Peripheral nerve injury or radiculopathy</td>
<td>0.2-3.2(^3)(^4)(^10)</td>
</tr>
<tr>
<td>Airway compromise due to airway edema or hematoma</td>
<td>1.7-6.0(^9)(^8)(^9)</td>
</tr>
<tr>
<td>Epidural hematoma</td>
<td>0.2-1.9(^3)(^4)(^6)</td>
</tr>
<tr>
<td>Radiculopathy</td>
<td>As above</td>
</tr>
</tbody>
</table>

In a cadaveric study, Taylor et al\(^21\) found injection of 30 mL indigo carmine dye through an intraesophageal nasogastric tube to be an unreliable method for detecting esophageal injury in the acute setting. The authors also tested a novel technique using proximal and distal placement of a Foley catheter to increase dye pressure. They showed improved, although still limited, capacity to diagnose esophageal perforation. When concern exists regarding the possibility of injury, consultation with a general or thoracic surgeon is recommended, as esophageal injury can be assessed directly during surgery or endoscopically following surgery. Placement of a feeding tube should also be considered for the patient with a suspected esophageal injury. The consequences of missed injury are high, with mortality rates reaching 20% even when the patient is treated within the first 24 hours; this increases to as high as 50% when treatment is further delayed.\(^2\) Evidence of infection

Dr. Riew or a member of his immediate family has received research or institutional support from Medtronic Sofamor Danek, has received royalties from EBI Biomet, has stock or stock options in Osprey Biomedical Corporation and Spine Medica Corporation, and is an unpaid consultant to Interpore-Cross, Spineology, and Medtronic Sofamor Danek. Dr. Ching or a member of his immediate family has participated in a speakers bureau or given paid presentations and has received research or institutional support from DePuy Spine. Dr. Hart or a member of his immediate family has received royalties from DePuy and SeaSpine; has received research or institutional support from Accumed, DePuy, and Medtronic; serves as a paid consultant to DePuy and Medtronic; and has participated in a speakers bureau or given paid presentations for AO, DePuy, Kyphon, and Medtronic. None of the following authors or a member of their immediate families has received anything of value from or owns stock in a commercial company or institution related directly or indirectly to the subject of this article: Dr. Daniels, Dr. Yoo, Dr. Birchard, and Dr. Kranenburg.
in the early postoperative period should alert the surgeon to the possibility of esophageal injury, and prompt reexploration of the wound should be done.

**Vertebral Artery Injury**

The vertebral arteries are the first branches arising from the subclavian arteries. They run within the transverse foramina of the cervical vertebrae, most commonly entering at the C6 level. After passing through the C1 vertebra, the vertebral arteries continue posteriorly and perforate the dura through the foramen magnum to supply the posterior circulation of the brain. The mean distance from the uncovertebral joint to the transverse foramen has been reported to be 5.5 mm in the subaxial vertebrae, although anatomic variants are common. Curylo et al reported a 2.7% incidence of unilateral artery displacement, with transverse foramen enlargement as far medial as the midvertebral body level.

The reported incidence of intraoperative vertebral artery injury is quite low. A review of 1,976 patients found a 0.3% incidence of iatrogenic vertebral artery injury during anterior cervical spine surgery. Avoidable mechanisms of injury include performance of an excessively wide corpectomy as well as loss of the vertebral midline or orientation, leading to an off-center or oblique corpectomy (Figure 1, A-C). Unrecognized vertebral artery tortuosity (Figure 1, D) or other anomalies, such as a vertebral artery located anterior to the transverse process, may also result in intraoperative injury. Soft lateral bone resulting from infection or tumor is another important risk factor.

In the event of a vertebral artery injury, bleeding should be controlled with direct tamponade, although an effort should be made to accomplish a more definitive means of control. Although proximal and distal ligation is an acceptable option when direct repair is impossible, the redundancy of the posterior cerebral blood supply is unknown. The risk of brain stem infarction following vertebral artery occlusion has been estimated to be 3.8% on the left side and 1.8% on the right. Intraoperative angiography before ligation is recommended to ensure adequate cerebral perfusion.

When technically feasible, repair of the vertebral artery injury is the preferred approach. Once active bleeding is controlled, the artery should be exposed at the level of the transverse process directly over the transverse foramen, to determine whether it should be ligated or repaired. This region of the transverse process is referred to as the costal process because of its similarity to the costovertebral joints within the thoracic spine (Figure 1, A).

After the longus coli muscle is elevated, a small curet is used to free the soft tissues adherent to the undersurface of the costal process, which can then be readily removed with a 2-mm Kerrison rongeur. This often results in a minor amount of venous oozing, which is controllable by injecting a hemostatic agent such as Floseal (Baxter, Deerfield, IL) into the transverse foramen. A right-angle clamp is then placed under the artery to facilitate the passage of vessel loops cephalad and caudad to the site of injury. Lifting up on the two vessel loops occludes the artery at the site of injury, allowing ligation or repair, depending on the severity of the laceration. Avoiding electro-
cautery as a means to control bleeding is recommended as it is generally ineffective and may cause injury to the cervical roots. Emergent consultation with a vascular surgeon may be required for intraoperative repair of the injury. Alternatively, injuries that appear to be controllable via direct tamponade may be treatable endovascularly via stent or coagulation, depending on the angio-graphic appearance of the contralateral circulation.

**Dural Tear**

The incidence of dural tear during anterior cervical spine surgery was reported by Emery et al to be 3.7%. Patients undergoing revision anterior cervical spine surgery and those with ossification of the posterior longitudinal ligament (OPLL) are at increased risk of dural tear. Depending on the location of the tear and the available exposure, the dura can in some cases be directly repaired. Widening the exposure and attempting a suture repair, with placement of fibrin glue or other sealant, can be successful. In general, even when a watertight repair is achieved, because of the lack of a closed fascial space (as exists in the lumbar spine), the surgeon may want to consider inserting a lumbar cerebrospinal fluid (CSF) drain. Upright patient positioning following surgery has also been shown to reduce intraspinal CSF pressure. Fistula formation and secondary airway compromise remain serious potential concerns with a persistent leak.

Belanger et al described the outcomes at 2-year follow-up of 61 patients who were treated with anterior cervical decompression and fusion for symptomatic OPLL. Eight patients had absent dura, and five developed a CSF fistula (8%). Given the significant risk of dural disruption, multilevel OPLL is probably best addressed with a posterior procedure, such as laminaplasty, or laminectomy and instrumented fusion, particularly in the presence of lordosis or flexible kyphosis. In patients with OPLL who require an anterior approach because of fixed kyphosis, the surgeon should be prepared for absent dura and plan for possible dural patch grafting and insertion of a lumbar CSF drain.

**Spinal Cord Injury**

The spinal cord is at risk for injury throughout all phases of anterior cervical spine surgery, with the reported incidence of acute iatrogenic spinal cord injury ranging from 0.2% to 0.9%. Patients with myelopathy, cervical kyphosis, spinal cord atrophy, or spinal instability and fractures through long, fused spinal segments are at increased risk of spinal cord injury. Strategies to prevent iatrogenic spinal cord injury include maintenance of systolic blood pressure >80 mm Hg and avoidance of excessive extension or distraction of the cervical spine during patient positioning.

Given the severe consequences of spinal cord injury, use of intraoperative neurologic monitoring with transcranial electric motor-evoked potential (tceMEP) monitoring and somatosensory-evoked potential (SSEP) appears to be prudent, especially for surgical procedures in which the spinal cord or nerve roots are at significant risk of injury, and in high-risk patients, such as those with marked instability or severe myelopathy. In a retrospective study of patients undergoing cervical spine surgery with SSEP and tceMEP monitoring, the sensitivity and specificity for detecting evolving motor tract injury with tceMEP was 100%, compared with a 25% sensitivity and 100% specificity with SSEP. Although definitive prospective data demonstrating the benefit of intraoperative neurologic monitoring are currently unavailable, we find it difficult to construct a credible argument against its use.

When a spinal cord injury is suspected, radiographic and/or direct examination of bone graft and hardware should be conducted to confirm the lack of direct spinal cord compression. Postoperative evaluation of patients with new neurologic deficits should include an emergent magnetic resonance imaging scan or computed tomography (CT) myelogram to evaluate for neurologic injury and to rule out hematoma or misplaced graft or hardware. Absent a structural lesion, treatment is largely expectant. The role of steroids remains controversial, despite a large prospective randomized trial supporting their use. Other interventions, such as maintenance of mean arterial pressure ≥90 mm Hg, controlled hypothermia, and pharmacologic agents (eg, erythropoietin, minocycline, Rho antagonists), although promising, are as yet unproved.

**Peripheral Nerve Injury**

Peripheral nerves are also at risk for injury during anterior cervical spine surgery, usually from traction or direct pressure on the brachial plexus or ulnar nerve during intraoperative patient positioning. Strategies for preventing adverse events include avoidance of excessive neck extension or cranial traction, palpation of the patient-padding interface at areas at risk for pressure injury, avoidance of overaggressive traction with tape on the patient’s shoulders, and use of intraoperative neurologic monitoring. Patients with spinal cord level injury who experience postoperative lower motor neuron deficits should undergo imaging to rule out potential sources of radicular compression. In the absence of neurologic compression, treatment is largely expectant, with most patients experiencing substantial recovery.

**Immediate to Early Postoperative Adverse Events: Within 1 Week**

**Acute Airway Compromise**

Acute airway compromise is a potentially life-threatening adverse event...
event associated with anterior cervical surgery. The reported incidence of reintubation following anterior cervical spine surgery ranges from 1.7% to 2.8%. Emery et al reported postoperative airway obstruction in 3 of 108 patients following anterior cervical decompression and noninstrumented fusion (2.8%), including 1 patient who ultimately died from postoperative aspiration pneumonia. Less severe airway compromise has been reported to occur in approximately 6% of patients.

Several events may contribute to postoperative airway obstruction, including hematoma formation, CSF leakage, hardware or bone graft displacement, and laryngeal or prevertebral soft-tissue swelling. In their prospective study of soft-tissue edema after anterior cervical discectomy and fusion, Suk et al found that peak swelling occurred on the second and third postoperative days. Swelling at the C2-C4 levels was more clinically significant than it was below C5. Other risk factors for airway compromise caused by prevertebral swelling include obesity, obstructive sleep apnea, surgical time >5 hours, revision surgery, history of asthma, exposure of three or more disk levels, and transfusion of more than four units of blood. Efforts to limit surgical times and avoid overzealous fluid replacement may reduce the severity of laryngeal edema.

Epstein et al recommended that patients be kept intubated after multilevel anterior cervical spine procedures until they demonstrate adequate ventilatory weaning parameters while off of sedation, satisfactory air leak around a deflated endotracheal tube balloon, and bronchoscopic evidence of minimal airway swelling. Diuresis, elevation of the head of the bed, and inhaled or intravenous steroid medications may also help reduce postoperative airway edema (Figure 2).

Algorithm demonstrating the management of postoperative airway compromise. A/P = anterior-posterior, POD = postoperative day, PPI = proton pump inhibitor.

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operatively may benefit from temporary tracheotomy.

Postoperative hematoma formation can also cause life-threatening airway compromise as well as less severe concerns, including persistent wound drainage and infection. The reported incidence of wound hematoma varies from 0.2% to 1.9%. Hematoma may occur due to venous bleeding or from an unrecognized or inadequately controlled arterial source. This adverse event can occur despite placement of a postoperative drain and adequate hemostasis at the time of wound closure due to increased blood pressure, coughing, vomiting, coagulopathy, or the use of an anticoagulant. Patients with life-threatening airway compromise and apparent swelling at the site of incision are candidates for urgent wound incision and drainage at the bedside or in the operating room.

**Epidural Hematoma**

Epidural hematoma, which may arise from arterial bleeding or from bleeding from the epidural veins, can cause progressive paralysis. A high index of suspicion should be maintained for patients with a new or progressive neurologic deficit. CT or magnetic resonance imaging can be considered for the neurologically stable patient, but urgent surgical re-exploration with removal of hardware and bone graft is appropriate for a patient with significant progressive neurologic deficit. When intraoperative neurophysiologic monitoring is used, it should be continued through wound closure and reversal of anesthesia, as neurologic deficits resulting from hematoma formation can develop at the end of the surgical procedure.

**Radiculopathy**

Radiculopathy can also occur during or after anterior cervical spine procedures, with a reported incidence of 0.2% to 3.2%. The most common radicular level is C5, which is especially at risk during multilevel anterior corpectomy. Ikenaga et al examined C5 radiculopathy in patients who underwent anterior decompression for cervical myelopathy and found an incidence of 3.2% (18 of 563 patients). The risk of C5 root palsy increases with the number of levels fused and is thought possibly to result from a traction mechanism as the cord shifts anteriorly following decompression.

**Intermediate Postoperative Adverse Events: 1 to 6 Weeks**

**Dysphagia**

Dysphagia is one of the most common adverse events following anterior cervical spine surgery. The etiology of postoperative swallowing difficulty is multifactorial, potentially arising from esophageal denervation, postoperative soft-tissue swelling, and scar tissue formation. Additional causative factors may include cervical immobilization, cervical hyperextension resulting from improper halo or collar positioning, prominence of anterior instrumentation, hematoma formation, and injury to specific nerves involved in swallowing.

Swallowing is dependent on several neurologic structures, including the pharyngeal plexus, hypoglossal nerves, superior laryngeal nerves (SLNs), and recurrent laryngeal nerves (RLNs). Anterior cervical spine surgery at all subaxial levels, but especially from C2 to C5, risks injury to the nerves of the pharyngeal plexus, which arise from the vagus nerve. Irritation or injury to these nerves can occur as a result of traction and can cause significant pharyngeal dysphagia. Surgical procedures above the level of C3 risk injury to the hypoglossal nerve, which is involved in both the oral and pharyngeal phases of swallowing. The SLN is especially at risk during exposure at the C3-C4 level. Injury of the SLN can cause laryngeal sensory impairment, which may potentially lead to significant dysphagia. Surgeries involving the lower cervical spinal levels from C5 to T1 place the RLN at particular risk of injury, which can cause a milder dysphagia, mainly during swallowing of liquids.

The reported incidence of dysphagia following anterior cervical surgery varies. It appears that medical records, compared with patient surveys, substantially underreport dysphagia, which may partially explain the wide range of incidence in previous reports. Recent studies have indicated that a substantial percentage of patients undergoing anterior cervical spine surgery experience some degree of postoperative dysphagia, with rates ranging from 28% to 57%. For most patients, postoperative dysphagia improves with time. Lee et al reported that the overall prevalence of dysphagia at 1-, 2-, 6-, 12-, and 24-month follow-up was 54.0%, 33.6%, 18.6%, 15.2%, and 13.6%, respectively. Only 1.3% of their patients reported moderate or severe dysphagia by 24 months postoperatively. Significant risk factors for postoperative dysphagia include a longer duration of preoperative neck or shoulder pain, age >60 years, female sex, operations on two or more levels, revision surgery, and thicker anterior cervical plates.

Patients with marked postoperative dysphagia should be evaluated with lateral plain radiographs or CT scan for bone graft dislodgement, retropharyngeal abscess, and postoperative edema or hematoma. Use of corticosteroids for dysphagia remains controversial. Patients with persistent dysphagia or with suspected aspiration due to coughing, choking, or atelectatic changes on chest radiographs should undergo speech pathology evaluation and active swallow therapy. In the patient with severe dysphagia that persists longer than 1 to 2 weeks, temporary feeding tube placement may be considered.

**Dysphonia**

Dysphonia is defined as a change in voice, ranging from hoarseness to
difficulty speaking. As with dysphagia, the etiology of dysphonia is multifactorial with contributing effects, including RLN injury, direct vocal cord trauma occurring during intubation, postoperative acid reflux, and laryngeal and vocal fold edema. The incidence of dysphonia is somewhat lower than that of dysphagia, with reported rates between 2% and 30% in the early postoperative period. The high variability in the reported rates may be partially related to underreporting but may also reflect differing study designs. Some authors reporting higher rates of dysphonia have focused on clinical dysphonia due to any cause, while others have studied vocal cord paralysis consistent with RLN palsy. For patients suffering prolonged dysphonia following anterior cervical spine surgery, referral to a speech pathologist or otolaryngologist is appropriate to help determine the cause.

One potentially preventable cause of dysphonia resulting from anterior cervical spine surgery is vocal cord paralysis secondary to RLN injury. This paralysis can occur intraoperatively as a result of compression, blunt trauma, nerve division or ligation, stretch-induced neurapraxia, or postoperative edema. Fortunately, most cases of RLN injury recover with time, although the reported rate of persistent symptomatic vocal fold paresis varies from 0.33% to 2.5%. Persistent vocal cord paralysis due to RLN injury causes hoarseness and vocal breathiness and should be assessed by an otolaryngologist.

In a cadaveric study of the effects of compression of the RLN, Apfelbaum et al found that pharyngeal tissues adjacent to the endotracheal tube were subject to significant compression, with an approximate threefold increase in endotracheal tube cuff pressure during deep retractor placement. They instituted a clinical protocol of endotracheal tube cuff pressure reduction to 15 mm Hg after retractor placement and found that the incidence of RLN injury dropped from 6.4% to 1.7% (P = 0.0002). However, a recent prospective randomized trial studying the effects of maintaining 20 mm Hg endotracheal tube pressure along with deflation following retractor placement failed to show a significant drop in the incidence of postoperative vocal fold immobility.

Controversy remains regarding the importance of a right- versus a left-sided approach to the anterior cervical spine with respect to risk of intraoperative RLN injury. Tew and Mayfield described the asymmetry between the right and left RLNs and argued that the anatomic loop of the nerve around the aortic arch on the left side was longer, more predictable, and more protected than the right-sided nerve, rendering it less susceptible to dissection and stretch injury when a left-sided surgical approach is used. A retrospective study in the otolaryngology literature indicated that 15 of 16 patients who presented to one clinic with aspiration and dysphagia following anterior cervical spine surgery had right-sided, unilateral vocal fold paralysis. However, large studies have reported low rates of RLN injury following procedures using a right-sided approach. Furthermore, Kilburg et al found no statistical difference in the rate of recurrent laryngeal nerve injury based on side of approach in their retrospective comparison of 418 patients treated with a right- versus a left-sided approach for one- and two-level instrumented anterior cervical disectomy and fusion. It is difficult to advocate one approach over the other on the basis of the current clinical literature.

**Bone Graft Extrusion**

Bone graft extrusion is a serious adverse event generally requiring revision surgery. It has been shown to be especially problematic following multilevel cervical corpectomy procedures. Wang et al reported a 6.4% overall incidence of bone graft migration or displacement in their review of 249 patients undergoing cervical corpectomy and autograft fusion. An increasing frequency of migration was noted with increasing levels of corpectomy, especially when ending at C7. Sasso et al reported a 6% failure rate after two-level anterior cervical corpectomy but a 71% failure rate for three-level corpectomy with fusion despite use of a fixed anterior cervical locking plate. Nonsegmental cervical locking plates spanning two or more levels have since been challenged on a biomechanical basis.

Other risk factors for graft extrusion include previous cervical laminectomy, recipient osteoporosis, and graft overtensioning, all of which may contribute to vertebral body fracture and secondary graft dislodgement. In general, a patient who requires corpectomy of two or more vertebral levels should be considered for simultaneous posterior instrumented spine fusion. Combining one- or two-level corpectomy with disectomy may result in airway compromise due to adjacent posterior fixation. Use of a buttress plate without simultaneous posterior instrumented fusion should be avoided because it likely does not reduce the incidence of graft extrusion and may result in airway compromise (Figure 3).

**Wound Infection**

Except in the instance of esophageal perforation or an immunocompromised patient, infection is relatively rare following anterior cervical spine surgery, with an estimated incidence of 0.2% to 1.6%. The anterior cervical spine is well vascularized and has substantial lymphatic drainage, making it a comparatively privileged surgical site. Acute wound infection following anterior cervical spine surgery is treated with irrigation.
and débridement of necrotic tissues, examination for esophageal injury, and targeted intravenous antibiotics. Resistant organisms and persistent infections should be considered for anterior hardware removal and re-grafting, with the addition of posterior stabilization and fusion if needed.

Acute Adverse Events Associated With Emerging Technologies

Off-label Use of Bone Morphogenetic Protein

BMPs have been shown to stimulate bone formation and fusion in several animal models and clinical applications. Currently, there are no US Food and Drug Administration (FDA)-approved applications of BMP in the cervical spine. Despite this, several spine surgeons have used recombinant human BMP-2 (rhBMP-2) in anterior cervical spine fusions as an off-label application.36,37 Recently, several reports have described clinically significant soft-tissue swelling following anterior cervical fusion augmented with rhBMP-2.36,37 (Figure 4).

Two studies examining rhBMP-2 augmentation of anterior cervical fusion reported rates of soft-tissue swelling severe enough to cause clinical concern or extended hospital stay in 23% to 27% of patients.36,37 In most cases, soft-tissue swelling resolved without consequence, although some patients have experienced airway compromise.36 The appropriate dosage of rhBMP-2 in anterior cervical spine fusion has not yet been determined, although it appears that the dose should be substantially less than what is contained in the small package (4.2 mg). Although rhBMP-2 may be of benefit in the anterior cervical spine in terms of fusion success, further research is needed to fully evaluate its efficacy and safety profile for this clinical application. If a surgeon is considering using BMP in anterior cervical spine surgery, the patient should be informed of the intended off-label use, including the reasons

Images of a 48-year-old man who underwent structural bone graft extrusion following corpectomy of C4 through C6 with fibular strut autograft for cervical myelopathy with kyphosis. A, Lateral radiograph immediately postoperatively demonstrating slight widening at the facet joints at C4/5 and C6/7 (arrows), which may be indicative of overdistraction. B, Lateral radiograph demonstrating fibular autograft dislodgement 16 days postoperatively. The patient experienced neck pain on waking from sleep. Neurologic and airway status were unchanged. C, Photograph of dislodged graft and buttress plate. Note fracture of the seventh vertebral body around the buttress plate, leading to graft dislodgement (arrow). D, Lateral radiograph following revision with a longer fibular allograft and posterior instrumented fusion from C3-T1 with lateral mass/pedicle screw-and-rod placement. The final clinical outcome was excellent, and neurologic improvement was maintained at 7-year follow-up.
underwent one- or two-level total disk replacement with the Bryan Cervical Disc (Medtronic Sofamor Danek, Memphis, TN) prosthesis. Early adverse events included increased radiculopathy or myelopathy (4%), prolonged dysphagia/dysphonia (4%), retropharyngeal hematoma requiring evacuation (1%), intraoperative prosthesis migration (1%), and overmilling of the vertebral body (1%). The impact of various designs on spinal alignment and prosthesis-specific adverse event rates and survival times will require long-term follow-up.

**Summary**

Anterior cervical procedures are frequently performed in the United States, with a high level of clinical success. Spine surgeons must be aware of potential adverse events and be vigilant during surgery and throughout the early postoperative period to reduce their occurrence and detect them expeditiously when they do occur. Proven strategies for avoidance, detection, and treatment have been reported for most of these adverse events. Adherence to these approaches will be helpful in optimizing clinical outcomes.

**References**

*Evidence-based Medicine:* References 15, 23, and 32 are prospective randomized trials, while 14 is a review of prospective randomized trials; thus, all are level I evidence. References 28-30 and 39 are prospective level II studies. References 1-13, 16-22, 24-27, 31, and 33-38 are level III, IV, or V case-control cohort, case series, or expert opinion papers.

Citation numbers printed in bold type indicate references published within the past 5 years.

13. Smith-Hammond CA, New KC, Pieterob R, Curtis DJ, Scharver CH, Turner DA: Prospective analysis of incidence and risk factors of dysphagia...


