Airway management for cervical spine surgery

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Cervical spine surgery is one of the most commonly performed spine surgeries in the United States, and 90% of the cases are related to degenerative cervical spine disease (the rest to cervical spine trauma and/or instability). The airway management for cervical spine surgery represents a crucial step in the anesthetic management to avoid injury to the cervical cord. The crux for upper airway management for cervical spine surgery is maintaining the neck in a neutral position with minimal neck movement during endotracheal intubation. Therefore, the conventional direct laryngoscopy (DL) can be unsuitable for securing the upper airway in cervical spine surgery, especially in cases of cervical spine instability and myelopathy. This review discusses the most recent evidence-based facts of the main advantages and limitations of different techniques available for upper airway management for cervical spine surgery.

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Anatomy of the cervical spine

Upper cervical spine

The occipitoatlantoaxial unit is one of the most complex articulating structures in the human body. This unit supports the head and allows the necessary range of movement of head and neck, while protecting the spinal cord and adjacent vital structures. The first cervical vertebra (C1), the atlas, is the uppermost vertebra, which lacks a distinctive body. However, it is characterized by having thick anterior and posterior arches that blend laterally into large masses. These lateral masses articulate with the occipital condyles of the skull via their large kidney-shaped depressions on their superior aspects. The weight of the skull is transferred into the second cervical vertebra (C2) by C1 flatter inferior surfaces. The C2 is characterized by its prominent odontoid process (dens). The odontoid process arises from the upper surface of the C2 body. The interval between the posterior aspect of the odontoid process and the anterior aspect of the posterior ring of the atlas is termed the posterior atlas dens interval and is the space available to the spinal cord. The space available to the cord at C1 may be divided into one-third odontoid, one-third cord, and one-third space. The one-third space allows for some encroachment of the spinal lumen without compromising the cord. In a normal spine, the space available for the cord is approximately 20 mm. Cord compression does not occur when the space available for the cord is > 18 mm but occurs if < 14 mm². Alar and apical ligaments fan upward from the odontoid process to insert into the anterior margins of the foramen magnum [2,3].

Lower cervical spine

The lower five cervical vertebrae are anatomically more typical vertebrae. The transverse processes are unique features with their laterally projecting costal processes and foramen transversarium, which transmits the vertebral artery through most of the cervical spine. The arches of the second to seventh cervical vertebrae articulate via horizontally oriented facet joints. Anterior and posterior longitudinal ligaments cover the anterior and posterior surfaces of the bodies of cervical spine vertebrae, respectively. The anterior longitudinal ligament extends over the anterior arch of the atlas to terminate as the anterior atlantooccipital ligament, while the posterior longitudinal ligament extends over the posterior surface of the axis and the odontoid process to terminate as the tectorial membrane. The tectorial membrane in turn inserts into the basiocciput [2]. The ligamentum flavum is a very thin structure in the cervical region but is thicker in the lumbar spine region. The ligamentum nuchae in the cervical spine region is the continuation of the supraspinous ligament [2].

Congenital anomalies of the cervical spine

Achondroplasia

It is characterized by a large skull with a narrow foramen magnum. The skull base is relatively small with short flattened vertebral bodies with large intervertebral disk heights [4], which prevent the extension of the head. Therefore, direct laryngoscopy could be very difficult or even impossible.

Down's syndrome

Down's syndrome (trisomy 21) is present in approximately 0.15% of the population. It is characterized by cervical ligamentous laxity and skeletal anomalies that could result in cervical instability. The subluxation of atlas (C1) anteriorly on the axis (C2) results in atlantoaxial instability, which occurs in about 15% of individuals with Down’s syndrome [4]. Therefore, several cases of severe neurologic complications have been recorded after surgical management or positioning in patients with Down’s syndrome [5]. The American Academy of Pediatrics and the Special Olympics have recommended routine radiologic screening for subluxation in patients with Down's syndrome. Atlantoaxial subluxation should be considered if the anterior atlantodental interval (ADI) is >4–5 mm in flexion–extension films of the cervical spine. Computed tomography (CT) scanning of the cervical spine...
should be considered before anesthesia for elective cases of Down’s syndrome patients to rule out atlantoaxial subluxation [5]. In emergent surgical cases, great care should be taken to minimize head and neck movements, which includes limiting extension on intubation and flexion and lateral motion for surgical access, as long as the diagnosis of cervical instability has not been ruled out. Therefore, fiber-optic endoscopy should be considered for intubation to limit neck motion. However, in emergent conditions where rapidly securing the airway is imperative, direct (DL) or video laryngoscopy could be used instead of fiber-optic endoscopy, which requires careful attention to minimize the neck motion during intubation. Of note, adults with Down’s syndrome have an increased prevalence of lower cervical spondylosis and cervical myelopathy. By age of 40 years, 70% of the patients with Down’s syndrome have evidence of spondylosis of clinical relevance [6]. Therefore, airway management in those patients should be handled carefully to minimize neck movement during intubation.

*Klippel–Feil syndrome and Klippel–Feil variant*

The Klippel–Feil syndrome is conventionally recognized as a triad of low-lying hairline, short neck, and cervical fusion abnormalities. Patients with cervical fusion abnormalities alone are said to exhibit the Klippel–Feil variant. Patients have very limited neck motion; hence, intubation is usually difficult [7]. Of note, Klippel–Feil syndrome has been described in trisomy 18, in association with Turner’s syndrome, and also as an isolated syndrome.

*Neurofibromatosis type (NF1)*

This is characterized by progressive cervical kyphosis, which may occur because of intrinsic ligamentous abnormality and abnormal bony architecture. The presence of cervical kyphosis could limit the neck extension resulting in difficult intubation. Furthermore, the resection of soft tissue or extradural neurofibromas could be complicated by the development of cervical kyphosis.

*Chiari malformation*

It is characterized by crowding of the posterior fossa by the neural elements and hindbrain herniation through the foramen magnum. Anomalies of the skull base in many patients with anomaly may include occipitalization of C1, fusion of C1 to C2, Klippel–Feil deformity, or cervical spina bifida occulta [8]. Therefore, these patients have limited neck extension, and hence intubation is difficult.

*Morquio syndrome*

Mucopolysaccharidosis type IV, more commonly known as Morquio syndrome, is a rare enzyme deficiency disorder that results in skeletal dysplasia. Another common aspect of this syndrome is odontoid dysplasia, resulting in atlantoaxial instability and spinal cord compression [9].

*Congenital cervical canal stenosis*

Congenital cervical canal stenosis is characterized by congenital decrease in the anterior–posterior diameter of the spinal canal, which could result in the development of cervical myelopathy. The diagnosis of congenital cervical stenosis should be considered in individuals with an anterior–posterior diameter of the spinal canal of <13 mm (normal 17–18 mm). There is a strong association between flattening of the cord within the narrowed spinal canal and the development of cervical myelopathy. The anterior–posterior cord compression ratio is measured by dividing the anterior–posterior diameter of the cord by the cord’s transverse diameter [10]. Patients with substantial flattening of the cord (banana-shaped spinal cord) and impaired neurologic function are diagnosed by an anterior–posterior ratio <0.40. The increase in this ratio to ≥0.40 is a strong predictor of recovery following surgery. It is imperative to maintain the neck in a neutral position during endotracheal intubation in the presence of myelopathy with congenital cervical stenosis to avoid injury to the spinal cord during the airway management.
Degenerative

Cervical spondylosis

A cascade of degenerative changes that most likely begins at the cervical disk causes cervical spondylosis. Age-related changes result in a progressive loss of disk viscoelastic properties.

The spinal cord is compressed anteriorly by disk herniation into the spinal canal and posteriorly by infolding of the ligamentum and facet joint capsule [3]. Moreover, the loss of height of vertebral bodies caused by disk herniation moves the bodies toward one another, resulting in further cord compression [3].

Patients with chronic renal failure are more prone to spinal degenerative disease. Destructive spondyloarthropathy (DSA) is the term usually used to describe a process occurring in hemodialysis patients, which affects the cervical spine. Therefore, the head movement of a patient with chronic renal failure should be minimized during endotracheal intubation and during surgery [11].

Inflammatory diseases affecting the cervical spine

Rheumatoid arthritis

Cervical spine disease is a common problem in patients with rheumatoid arthritis (RA). The diagnosis of cervical involvement in RA patients can be problematic as the cervical spine disease can be completely asymptomatic. Therefore, screening for this problem is important in conditions requiring hyperextension of the neck such as intubation at the time of surgery. Bone erosions and atlantoaxial subluxation characterize cervical involvement in RA patients [13]. The destruction of the transverse ligament, the alar ligament, and the apical dental ligament by pannus [12] formation could result in several types of atlantoaxial subluxation. Anterior atlantoaxial subluxation is generally defined as an atlantodental distance of ≥3 mm. The risk of cord compression increases with an anterior atlantoaxial distance >9 mm [14]. However, a posterior atlantoaxial distance of <14 mm is considered a more reliable criterion for the risk of irreversible neurological injuries [13]. Of note, posterior atlantoaxial subluxation is less common than the anterior one and it is diagnosed when the anterior arch of C1 is displaced posteriorly over the dens. Vertical subluxation is defined as a tip of the odontoid process located 4.5 mm above the McGregor line. The McGregor line connects the post—superior aspect of the hard palate with the occiput [14] on standard radiography (Figs. 1 and 2). Vertical atlantoaxial subluxation could result in brain-stem compression at the level of the foramen magnum; therefore, it is considered a life-threatening condition. It is worth mentioning that 17% of RA patients in whom involvement of the cervical spine is diagnosed with standard radiography, CT, or magnetic resonance imaging (MRI) are asymptomatic. Therefore, diagnostic radiographs of RA patients with disease duration of >2 years should include open-mouth, lateral neutral, and lateral flexed projection. Moreover, plain radiography should be performed in all patients with RA before any surgical procedure, regardless of symptoms [15].

Ankylosing spondylitis

Ankylosing spondylitis is an inflammatory arthropathy marked by infiltration of ligaments and joint capsules by granulation tissue, which progressively undergoes fibrosis, calcification, and eventually ankylosis [8]. Complete ankylosis of the cervical spine, characteristically in the flexed position, is the end result. Trivial injuries, especially of the extension type, may result in cervical fracture. Therefore, conscious, fiber-optic intubation with minimal movement of the neck during intubation should be considered in those patients to avoid cervical injury [16,17].

Infectious

Grisel’s syndrome

Sir Charles Bell described a relationship between pharyngeal disease and cervical spine problems in 1830 in a patient with a syphilitic pharyngeal ulcer that resulted in lethal spinal compression. The term
**Fig. 1.** Measurement of atlantodental distance. Connecting line from posterior margin of the anterior arch of the first cervical vertebra to the anterior margin of the odontoid process. (Reprinted from Del Grande M, Del Grande F, Carrino J, Bingham CO, 3rd, Louie GH: Cervical spine involvement early in the course of rheumatoid arthritis. Semin Arthritis Rheum 2014; 43: 738–44 With permission from Elsevier).

**Fig. 2.** Measurement of superior migration of the odontoid process. Perpendicular distance from the center of the pedicles of the second cervical vertebra to the connecting line from the anterior arch to the spinous process of the first cervical vertebra. Normal value is >13 mm. (Reprinted from Del Grande M, Del Grande F, Carrino J, Bingham CO, 3rd, Louie GH: Cervical spine involvement early in the course of rheumatoid arthritis. Semin Arthritis Rheum 2014; 43: 738–44 With permission from Elsevier).
“Grisel’s syndrome” was coined by Grisel a century later as nontraumatic subluxation of the atlantoaxial joint. Grisel’s syndrome most frequently occurs following otolaryngologic procedures including tonsillectomy, adenoidectomy, and mastoidectomy. Head and neck infections now comprise the second most common cause [18]. Therefore, great care should be taken to avoid spinal cord injury by atlantoaxial subluxation.

**Kinematics**

Nodding of the head originates predominately through flexion and extension at the joint between the atlas and the occipital bone, the atlantooccipital joint. The distance from the posterior arch of the atlas to the occipit is termed atlantooccipital gap (AOG), and a narrow AOG has been considered as the common cause of difficult intubation [19]. Head extension in patients with narrow AOG during intubation can make visualization of the larynx during laryngoscopy and forward displacement of the larynx difficult [20].

Dynamic factors in the cervical spinal column affect the degree of cord compression. Both hyperextension and flexion could result in narrowing of the spinal canal and consequently cord compression. Patients who lack cord compression statically may compress the cord dynamically, causing some myelopathic symptoms. Pinching of the spinal cord between the inferior—posterior margin of a vertebral body and the superior edge of the lamina caudate (Fig. 3) [3] could occur as result of retrolisthesis of the vertebral body. Poisson effect was described by Breig and colleagues [21]; they showed that the spinal cord stretches with flexion of the cervical spine and shortens and thickens with extension. As the cord gets thicker in extension, it becomes more susceptible to pressure from the infolded ligamentum flavum or lamina. Moreover, in flexion, the stretched cord may be susceptible to higher intrinsic pressure of a disk or vertebral body anteriorly [22]. Prone positioning is often associated with modest degrees of extension; therefore, the cord might sustain excessive pressure induced by soft encroachment on the spinal canal with extension and aggravated by the preexisting canal compromise. The clinical relevance of these findings is that a persistent malposition of an abnormal neck results in cord ischemia and neurologic injury. Prone positioning is also associated with increases in vena cava pressures that can further reduce cord blood flow already compromised by cord compression, by increasing resistance in the venous outflows channels [8].

**Stability**

Stability is defined as the ability of the spine to protect the cord and nerve roots from either damage or irritation under physiologic stresses by maintaining the relationships between vertebrae so as to achieve this purpose. Moreover, there will be no new development of incapacitating deformity or pain.
due to structural compensational changes [8]. Instability caused by physiological loading creates patterns of vertebral displacement that endanger the spinal cord or nerve roots.

Spinal failure is deemed to have occurred when the upper vertebrae rotate 90° in the lower vertebral or when the motion segment separated. Instability occurs when the elements of one column are disrupted. However, the stability can still be maintained despite column disruption if one element of the injured column is still preserved. Of note, in clinical situations, it is better to assume that the spine is potentially unstable until proved otherwise [23]. Anterior column disruption tends to make the spine unstable in extension, and posterior column damage favors instability in flexion. Cervical instability can be diagnosed by radiological measurements as follows [24]:

**Translation**

C1–2: anterior atlantodental interval (ADI) > 5 mm, posterior ADI < 13 mm.
C2–T1: > 3.5 mm between points on adjacent vertebrae.

**Angulation**

> 11° between vertebrae.

The anterior column consists of the posterior longitudinal and its anterior structures, while the elements of the posterior include those behind the posterior ligament.

**Dynamic forces of cervical spine mobility during glottic and supraglottic intubation techniques**

**Direct laryngoscopy**

The anesthesiologist must align the pharyngeal and laryngeal axis during intubation. In addition, to place an endotracheal tube (ET) via DL, the anesthesiologist must be able to obtain a line-of-sight view between the eye and much of the glottis to allow placement of the ET through the trachea. The primary force applied by the laryngoscope is an upward lift, resulting in extension of the occiput and atlas interspace. Evidence suggests that DL results in maximal extension at the occiput and atlas and flexion below the axis [3]. External stabilization methods may reduce movement during DL, but they will also make glottic visualization more difficult. The primary force applied during DL is an upward lift with little angular force. This force can be as high as 50–70 N (45 N I sufficient to lift 4.5 kg or 10 lbs). Therefore, greater force is applied in difficult laryngoscopies especially with patients with cervical spondylosis [1–3]. The use of a Mac 3 blade results in near-maximal extension at the occiput and C1 (with the posterior arch of C1 touching the skull), with flexion below C2–3. There are only minimal differences with the use of either curved or straight blades. In cadavers with an instability created at the C5–6 space, Donaldson [25] demonstrated that oral techniques for intubation using DL caused more motion than blind nasotracheal intubation. However, the extent of motion caused by pre-intubation maneuvers such as chin lift/jaw thrust is similar to other intubation techniques. In a follow-up study, Donaldson [26] showed that oral intubation using DL caused more motion than blind nasal intubation at the unstable C1–2 spinal segment; however, change in the space available for the spinal cord was similar between the two techniques. Furthermore, the chin lift/jaw thrust caused more motion than either nasal or oral intubation. The authors therefore suggested utmost caution while performing pre-intubation maneuvers such as chin lift/jaw thrust. Of note, cricoid pressure could produce significant movement at an unstable C5–6 segment but not at the C1–2 region. Therefore, the application of cricoid pressure is potentially safe for cervical spine injuries above the C5–6 segment [25].

**Video laryngoscopes**

The use of video laryngoscopes for endotracheal intubation has been welcomed as an efficient tool for difficult upper airway management. However, the use of video laryngoscopes in cervical spine surgeries is still debatable. The use of the GlideScope produced better glottic visualization compared to DL during tracheal intubation under general anesthesia with neuromuscular blockade and manual in-line stabilization (MILS). However, it did not significantly decrease movement of the non-pathological C-spine when compared with DL [27]. Turkstra [28] showed that the use of GlideScope for
Endotracheal intubation reduced the C-spine motion by 50% only at the C2–5 segment when compared with the use of a Macintosh blade, but the C-spine motion at the occiput–C1 junction, C1–2 junction, and C5–thoracic segments remained unchanged. The cervical spine motion during endotracheal intubation is not linear to the force exerted by the laryngoscope. Although intubation with the Airtraq video laryngoscope exerted only 20% of the force required by the Macintosh blade (10 vs. 50 N), it resulted in 67% occiput–C5 motion (20 vs. 30°). Therefore, the video laryngoscopes should not be considered a safe tool to necessarily result in proportionately less cervical spine motion [29].

**Supraglottic devices**

In a cadaveric study, Keller [30] demonstrated that both standard (LMA) and intubating (ILM) laryngeal mask airways exerted transient pressures of >220 cm H₂O against the cervical vertebrae during insertion. The maximal cervical pressures at an intracuff pressure of 60 cm H₂O were 10 cm H₂O with LMA and 95 cm H₂O with ILM. However, the maximal cervical pressures could reach up to 394 cm H₂O with the handle pressure of ILM. Therefore, the authors recommended that laryngeal mask devices be used carefully in patients with an unstable cervical spine. A case report of posterior longitudinal ligament infarction and quadriplegia in a patient with an undisclosed unstable neck was associated with the use of LMA for laparoscopic cholecystectomy [31]. Of note, the pressure generated within the upper esophagus and against C6 during cricoid pressure is usually 60 cm H₂O [32].

**Fiber-optic intubation**

Sahin et al. [33] studied upper cervical vertebral motion during intubation using DL, LMA, and fiber-optic intubation. The fiber-optic method was the method of choice to produce the least motion in the upper cervical spine. The least movement of cervical spine using fiber-optic intubation has been confirmed in similar study by Brimacombe et al. [34] Moreover, the use of fiber-optic intubation was helpful in reducing the incidence of postoperative airway obstruction to 1% as compared to 14% in patients intubated without fiber-optic technique during the cervical spine surgeries as the fiber-optic intubation technique induced the least trauma to the upper airways compared to other techniques [35].

It should be mentioned that all the studies for studying different techniques of intubation on the cervical spine movements have been performed on either cadavers or healthy patients. None of those studies were performed on patients with cervical spine pathologies such as RA, cervical spondylosis, myelopathy, or other unstable cervical spine pathologies. Moreover, there were no outcome studies to follow up the effects of different intubation techniques on patients with cervical spine pathologies who underwent cervical spine surgeries. Therefore, fiber-optic intubation is still the ideal and preferred method for upper airway management during cervical spine surgeries.

**Airway management for cervical spine surgery**

**Airway management for elective surgeries**

Careful preoperative airway assessment is essential to ensure the suitable airway technique for upper airway management for cervical spine surgery. Impaired cranio cervical junction extension usually results in reduced mouth opening and poor mandibular protrusion. Therefore, they appear to be better indicators of difficult DL rather than reduced neck extension [38]. The anesthesiologist should examine the patient for the presence or absence of Lhermitte's sign, sometimes called the “barber chair” phenomenon. Lhermitte’s sign is an electrical sensation that runs down the back and into the limbs from involvement of the posterior columns and is produced by flexion or by extension the neck. This sign suggests compression of the spinal cord in the neck from any cause such as cervical spondylosis, disk herniation, tumor, or Arnold–Chiari malformation. The presence of Lhermitte’s sign should alert the anesthesiologist to take extra care in maintaining a neutral head position during intubation. Therefore, conscious fiber-optic intubation is the preferred method in the presence of Lhermitte’s sign to minimize the neck movement during intubation [3]. In addition, patients with myelopathy, unstable neck fractures, or spinal canal stenosis should be intubated using awake fiber-
optic intubation to maintain the neutral neck position during intubation [36]. The use of awake fiber-optic intubation in these conditions will further help maintain the protective reflexes and allow neurological examination and even positioning after intubation [3].

Cervical spondylosis, the most common indication for cervical spine surgery, suggests difficult laryngoscopy. It has been suggested that anterior osteophytes can make DL difficult in those patients.

Radiological imaging should be examined for patients with radiculopathy without myelopathy before intubating them unconsciously to exclude spinal cord stenosis or instability. In the author's opinion, unconscious fiber-optic intubation is the preferred technique; however, DL or video laryngoscopy can be performed with regard to minimizing the neck movement during intubation.

In summary, for airway management during elective cervical spine surgery, awake fiber-optic intubation is the best method to maintain neck neutrality during intubation in symptomatic patients and in those for whom intubation is predicted to be difficult [37]. If other techniques will be used for intubation during cervical spine surgery, minimizing neck movement during intubation is of utmost importance to avoid spinal cord injury.

**Acute airway management for emergent unstable cervical spine**

Before the 1970s, the immobilization of the cervical spine was not consistently used; therefore the incidence of secondary injury was estimated to range from 10% to 25% [38]. The standard of care in the 1980s and 1990s was DL and orotracheal intubation with MILS [39]. However, the available literature does not support the efficacy of MILS in limiting dangerous spinal movement during DL and may even increase subluxation at unstable segments [40,41]. In 16 cadavers with partial (posterior) instability at C4–5, MILS did not decrease abnormal angulation at the unstable segment during DL in comparison to DL alone [42]. In a subsequent study in 10 cadavers with complete instability at C4–5, MILS increased the amount of subluxation at the unstable segment during intubation as compared to DL alone [40]. Considering nine anesthetized and pharmacologically paralyzed patients, MILS resulted in worsening glottic visualization in six patients and failed intubation in two. Maximum laryngoscope pressure at the best glottic view was greater with MILS than without (717 ± 339 mmHg vs. 363 ± 121 mmHg, respectively) [43]. The impaired laryngoscopic view by MILS and the likelihood of failed intubation [44] may lead to hypoxia and secondary neurologic injury [45,46]. Therefore, MILS should be used when it does not impair intubation attempts.

Video laryngoscopy can be performed with MILS to obtain a better laryngeal view than with DL and orotracheal intubation [47]. Conscious fiber-optic intubation is still considered the best way to cause minimal movement of the cervical spine during intubation [34]. However, the use of conscious fiber-optic intubation requires a conscious, cooperative patient; in addition, it can be impeded by secretions and bleeding and is slower than DL [48].

It is worth mentioning that hard collars allow 72–73% of normal flexion and extension. The combination of bilateral sandbags secured with 3-in. cloth tape and Philadelphia collar is the most effective stabilizing collar, allowing for almost no neck flexion, although 35% of normal extension is possible [2,49].

In conclusion, in emergent surgery for unstable cervical spine, intubation should be performed with minimal extension and flexion of the cervical spine. In other words, the aim is to maintain the cervical spine in a neutral position during intubation.

**Neurological injuries caused by airway management for cervical spine surgeries**

According to the latest ASA closed claims, analysis for cervical cord, root, and/or bony spine injuries (n = 48) comprised 0.9% of all claims for general anesthesia (n = 5231) [1]. The majority of those cases were reported in cervical spine surgeries. Airway management was the cause of neuronal injury in 11% of cases. Almost all patients in this analysis were intubated for their procedure, and at least 87% of these intubations were accomplished by DL. Fiber-optic intubation and cervical spine stabilization techniques were used infrequently. Of a total of six claims, cervical injury was attributed to airway management. Of note, difficult airway management was the cause of injury in six cases (10%). The authors suggested degenerative disease of the cervical spine as the independent risk factor for perioperative
cervical cord injury in the absence of anatomic instability [1]. In cervical spondylosis, the cord compression present in the neutral position can markedly increase either with cervical flexion or, more commonly, with extensions such as during DL. Neural injury during DL in patients with cervical spondylosis can result in central cord syndrome (CCS). CCS, first described by Schneider in 1954, is characterized by injury to lateral corticospinal tracts. CCS presents, on a spectrum, weakness confined to the hands and forearms with sensory preservation to complete quadriplegia. The upper extremities, particularly the hands and forearms, are more severely affected than the lower extremities [50–52]. Therefore, airway management in patients with cervical spondylosis should be performed with great care, preferably with fiber-optic intubation to avoid neck movement during intubation.

Airway complications associated with cervical spine surgeries

Airway compromises and obstructions requiring active interventions such as reintubation or tracheostomy are rare but could have catastrophic complications. The most common cause for an airway compromise after cervical spine surgery, especially anterior cervical spine surgery, is caused by edema of the laryngopharynx and prevertebral soft tissues [53]. Hematoma, cerebrospinal fluid leak, angioedema, and graft or plate dislodgment [54] are other causes for airway obstruction after cervical spine surgery. Recently, the off-label use of bone morphogenetic protein (BMP) for arthrodesis was associated with a progressive inflammatory response, and delayed onset of airway edema [55] showed that airway complications associated with the anterior cervical spine developed in 6% of cases. The main predisposing factors for airway compromise were prolonged procedures (>5 h) exposing more than three vertebral levels that include C2, C3, or C4 with >300 ml of blood loss. However, the authors did not find that the history of myelopathy, spinal cord injury, pulmonary problems, anesthetic risk factors, and the absence were the predisposing factors for airway complications. The average time for the development of airway complications after anterior cervical spine surgery ranged from 23 to 37 h [54]. Epstein et al. [56] demonstrated that the risk factors associated with postoperative emergency airway management following cervical spine surgery included surgery time >10 h, obesity (>220 lbs), anterior corpectomy with fusion with C2 >4 units of transfused blood, a second anterior corpectomy with fusion, severe preoperative neurologic deficit, asthma, cerebrospinal fluid fistula, and age >65 years (Table 1). Terao Y et al. [57] identified combined anterior—posterior cervical spine surgery as a major risk factor for postoperative emergency airway management. Of note, a longer operative time would be accompanied by a longer period of retraction, an increase in local tissue edema, trauma, and more postoperative pharyngeal swelling. Therefore, operative time duration was identified as a risk factor for airway complications after cervical spine surgeries [58]. For patients with risk factors to develop postoperative airway compromise, delayed extubation, monitoring in an intensive care unit, and elevation of the head of the bed should be considered in postoperative period.

The airway compromise after cervical spine surgery can produce a spectrum of clinical findings. The patient can complain of difficulty in talking and breathing in early stages to dyspnea, cyanosis, and inspiratory stridor in late stages. Airway compromise after cervical spine surgery can be identified in lateral radiography and CT as prevertebral soft tissue edema and constriction of the airway lumen [53].

Airway compromise after cervical spine surgery is an emergency situation to help avoid brain anoxia and catastrophic outcomes. The patient should be managed in intensive care or operating room.

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<td>Blood loss&gt;300 ml</td>
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with the surgical team available to perform surgical airway if needed. The first step is to administer 100% oxygen via a face mask. Bag–mask ventilation should be tried first to improve the patient’s oxygenation before intubation. Conscious intubation by fiber-optic technique is the preferred method to avoid further trauma to the upper airway. If DL is the chosen method, it can be performed by either direct or video laryngoscope techniques. In the author’s opinion, video laryngoscope is better than DL in these conditions. It should be remembered that visualization of anatomic landmarks and endotracheal intubation can be challenging due to edema of the pharyngeal wall, epiglottis, and vocal cords. The first attempt is always the best chance for intubation. If intubation is unsuccessful, a surgical airway will need to be established by cricothyroidotomy. In the case of airway compromise by wound hematoma with failed initial intubation attempts, the surgical wound is opened and blood clot removed. Following wound decompression, another trial of bag–face ventilation is initiated. If adequate ventilation is not possible using the bag–mask technique, LMA can be inserted to facilitate ventilation. If intubation is not rapidly achieved, a surgical airway is established by cricothyroidotomy. In the author’s experience, fiber-optic intubation via LMA as a conduit using the entrée technique can be successful in patients with difficult airways [59].

A recent case report demonstrated that catastrophic neurological complication of emergent postoperative endotracheal intubation resulted in two cases of quadriplegia after cervical spine surgeries. The authors attributed the quadriplegia to excessive cervical extension by multiple attempts with direct laryngoscopy [60]. For a full discussion of postoperative complications after cervical spine surgery, the reader may refer to the chapter “Postoperative Complications of Spine Surgery.”

In conclusion, airway management for cervical spine surgery is the cornerstone for successful anesthetic management. Endotracheal intubation should be performed with minimal neck movement to avoid spinal cord injury. The anesthesiologist should be familiar with different techniques of airway management and their effects on cervical spine movement during intubation.

### Practice points

- Direct laryngoscopy results in extension at the occiput and the atlas and flexion below the axis.
- Direct laryngoscopy is not suitable for endotracheal intubation in cases of cervical myelopathy and instability.
- Manual in-line stabilization can impair glottic view, increase subluxation, and even result in failed intubation.
- Cervical spine movement using video laryngoscopy is not relatively better than with direct laryngoscopy.
- Fiber-optic intubation is still the safest technique for upper airway management for cervical spine surgery to ensure minimal neck movement during intubation.
- The crux for upper airway management for cervical spine surgery is to maintain the neck in a neutral position with minimal movement during intubation.

### Research agenda

- Define outcomes for different techniques for intubation during cervical spine surgery.
- Improve technologies in order to minimize the neck movement and maintain neutral position for upper airway management during cervical spine surgery.
- Reexamine the role of manual in-line stabilization in randomized control trials.
- Create national database to compare the different techniques of upper airway management during cervical spine surgery and their complications.
References


