Curr Anesthesiol Rep (2013) 3:197–204
DOI 10.1007/s40140-013-0022-9

NEUROANESTHESIA (JJ PASTERNAK, SECTION EDITOR)

# Airway Management in Cervical Spine Injury

**Daniel A. Diedrich · Peter S. Rose · Daniel R. Brown**

Published online: 22 June 2013
© Springer Science+Business Media New York 2013

**Abstract** Airway management in patients with cervical spine injury is a difficult and challenging task. Attention to head positioning and stabilization during the initial evaluation and airway management is critical in the care of these patients in order to minimize the risk of secondary neurologic insult. Awareness that these patients are at risk for airway obstruction is critical. A systemic approach and development of an individualized airway plan is necessary for optimal management of patients with cervical spine injury.

**Keywords** Cervical spine · Cervical spine injury · Spine injury · Airway management

## Introduction

Anesthesia providers are frequently called to perform airway management in patients with cervical spine injury. This may be performed emergently at the time of initial presentation for physiologic instability or electively in the setting of a planned general endotracheal anesthetic. Spine fractures may be associated with spinal cord injuries at presentation. In addition, patients with fractures may be at risk for secondary neurologic injury from fracture impingement or subluxation. To minimize the risk of secondary injury, the spine must be stabilized while the airway is managed. In this article, we provide practical knowledge about cervical spine injuries as well as discuss a systematic approach to airway management in this patient population.

D. A. Diedrich (✉) · D. R. Brown
Department of Anesthesiology and Critical Care Medicine, Mayo Clinic College of Medicine, 200 First St SW, Rochester, MN 55905, USA
e-mail: diedrich.daniel@mayo.edu

D. R. Brown
e-mail: brown.daniel@mayo.edu

P. S. Rose
Department of Orthopedic Surgery, Mayo Clinic College of Medicine, 200 First St SW, Rochester, MN 55905, USA
e-mail: rose.peter@mayo.edu

## Anatomy

The cervical spine is composed of seven cervical vertebrae (C1-7). The first cervical vertebrae (C1) is also referred to as the atlas and has two lateral masses with smooth superior surfaces that articulate with the occipital condyles at the base of the skull at the level of the foramen magnum. The atlas has no vertebral body and no spinous process, but does have lateral transverse processes with transverse foramina through which the vertebral arteries pass. The second vertebral body (C2, also known as the axis) is characterized by an anterior process (odontoid or dens) that protrudes upwards from its vertebral body into the ring of C1. The anterior articular surface of the dens articulates with the posterior surface of the anterior arch of C1; its position is maintained by a complex set of ligaments including the apical, alantodental, and alar ligaments.

The remaining five cervical vertebrae (C3-C7) are anatomically similar and gradually increase in size. Similar to C1 and C2, they have bilateral transverse foramina through which the vertebral arteries ascend. Running superiorly and inferiorly on the anterior and posterior surfaces of the vertebral bodies are the anterior and posterior longitudinal ligaments. The ligamentum flavum connects the adjacent lamina posteriorly, and the spinous processes are connected by the interspinal and supraspinal ligaments. Intervertebral

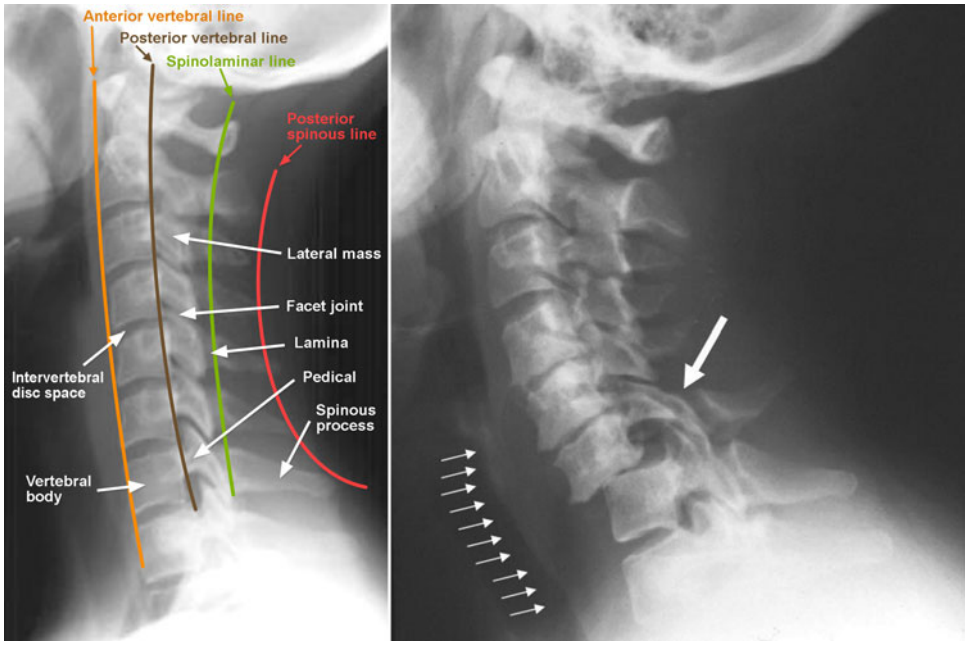



**Fig. 1** **a** Normal cervical spine anatomy and anatomic alignment. **b** C6/7 fracture dislocation (*large arrow*) disrupts this normal alignment and results in prevertebral soft tissue swelling (*small arrows*)

disks reside between adjacent vertebral bodies and are composed of an external annulus fibrosus surrounded by an internal nucleus pulposus. The spinal cord lies within the vertebral canal and the cervical nerve roots exit in the foramina between each vertebra [1].

The normal anatomic alignment of the cervical spine and typical lines that are used to assess alignment and injury are demonstrated in Fig. 1a, b, respectively.

## Biomechanics

Approximately 50 % of cervical flexion/extension occurs through the atlanto-occipital joint; similarly, ~50 % of rotation occurs through the atlanto-axial joint. The remaining flexion, extension, rotation, and lateral bending occur through the subaxial spine (C3–T1). Motion gradually decreases with age [2–4].

The cervical spine normally maintains a lordotic alignment which helps to position the head in space with respect to the body and also helps to absorb and dissipate any energy from impacts. Most cervical spine injuries lead to kyphosis, and many are relatively unstable in flexion (which imparts a further kyphosing movement to the spine). This has important implications for positioning for airway management.

Although most patients are served well with a standard collar and backboard for spine immobilization, two categories of patients require special consideration. The first is pediatric patients; the relative growth of the skull precedes the growth of the chest (leading to a large head-to-body ratio). For this reason, children need a blanket or other support beneath their chest to prevent being forced into kyphosis. The second is patients with rigid, kyphotic spines. This is often seen in patients with ankylosing spondylitis or diffuse idiopathic skeletal hyperostosis. These patients have a rigid stooped forward posture and will require elevation of their head with blankets or pillows to maintain their natural "neutral" position. Placing these patients on a standard backboard will lead to an abnormal lordotic force about the spine, and the rigidity of their spines will potentially transmit this force to any site of injury.

Immobilization does pose risks of airway obstruction and obscuring other injuries. In the case of penetrating trauma without neurologic deficit, clinically significant spinal injury is rare, and providers must weigh the risk of concurrent blunt trauma and occult spine injury with the impediments of strictly maintained spinal immobilization [5].

## Spine and Spinal Cord Injury

In a survey of 165 trauma centers, the incidence among trauma patients of cervical spine injury was 4.3 % and cervical spinal cord injury was 1.3 % [6]. Spinal cord injuries may be complete (with no motor or sensory function below the level of injury) or incomplete (with at least some motor and/or sensory function remaining).

Post-injury patients will often exhibit spinal shock soon after their injury. This is manifested by paralysis, hypotonia, and areflexia below the level of injury and is felt to be due to transient dysfunction of the spinal cord following injury rather than physical derangements of the spinal cord. The return of the bulbocavernosus reflex is a clinical sign that

spinal shock is no longer present. This reflex is tested by observing contraction of the anal sphincter with stimulation of the glans penis, vulva, or a tug on a urinary catheter. Although complete spinal cord injuries have a very poor prognosis for recovery, the presence of spinal shock can make it difficult to characterize an injury as complete or incomplete at initial presentation as incomplete injuries may appear more severe because of the transient neurologic dysfunction of spinal shock. High cervical injuries may paralyze or weaken diaphragm and chest wall motion leading to respiratory compromise. Neurogenic shock (a different entity than spinal shock) is characterized by hypotension and bradycardia due to loss of sympathetic tone and may lead to physiologic compromise, particularly if other injuries are present.

The vast majority of spinal cord injuries are due to fractures and/or dislocations (central cord injuries may be seen without fracture in patients with acquired or congenital spinal stenosis). Injuries of the cervical spine are commonly separated into upper cervical injuries (occiput through the C2/3 articulation) and subaxial cervical injuries (C3–T1) [7].

Common upper cervical injuries include atlanto-occipital injuries, C1 ring fractures, odontoid fractures, and spondylolisthesis of the axis. All of these injuries share a risk of retropharyngeal edema or hematoma that can compromise the airway as well as the potential for high cervical spinal cord injury with respiratory insufficiency due to paralyzed or weakened diaphragm and accessory muscles. Atlanto-occipital injuries are rare injuries at high risk for secondary deterioration *particularly with any applied traction*. These injuries are recognized by subluxation or dislocation of the atlantooccipital joint. C1 ring fractures (also known as Jefferson-type fractures) are commonly seen with axial loading. Provided the transverse ligament remains competent, most of these injuries can be treated nonsurgically. Odontoid fractures may result from hyperextension or hyperflexion injuries and may occur in elderly patients with low energy falls and osteoporosis. Traumatic spondylolisthesis of the axis (so called hangman's fractures) have a fracture that passes through the neural arch of C2 and may be due to flexion, extension, or distraction.

Injuries to the subaxial cervical spine may be due to a variety of applied forces. Flexion–compression injuries range from minor compression fractures of the vertebral body(ies) to burst-fracture dislocations. Vertical compression injuries (from axial loading) lead to compression and/or burst-type fractures. Flexion distraction injuries lead to facet dislocations. Extension compression injuries cause posterior arch fractures and potential traumatic spondylolisthesis. Extension distraction injuries can lead to teardrop fractures, and lateral compression injuries will injure lateral masses, facets, and potentially cause asymmetric vertebral body compression.

Cervical spine injuries exist along a spectrum from minor fractures treated with a collar and rapid mobilization to devastating and potentially fatal injuries associated with severe neurologic compromise. The highest risk fractures for further deterioration prior to definitive management are those associated with neurologic deficit, those associated with a subluxation or dislocation, and those associated with a burst-type fracture and compromise of the spinal canal; attention to head positioning and stabilization during airway and other patient management is critical in the care of these patients.

## Assessment of Cervical Spine Injury

The initial assessment of a trauma patient can be divided into the primary and secondary survey. The primary survey involves identification of immediate life-threatening injuries and initiation of stabilizing measures. This practice involves protocols described in Advanced Trauma Life Support® (ATLS) [8] and includes spinal immobilization as outlined above.

Once initial stabilization of the patient has occurred, a systematic head-to-toe evaluation (secondary survey) should then take place. Information gathered during this process will be used to assess for spinal and spinal cord injury. The secondary survey includes a detailed history, physical examination, and targeted diagnostic studies.

### History

Certain preexisting medical conditions (rheumatoid arthritis, Downs syndrome, ankylosing spondylosis, etc.) can predispose the patient to cervical spine injury. Determining the mechanism of injury as well as any specific involvement of the head, neck and upper body is critical. It is also important to determine any level of intoxication (alcohol or other) or evidence of closed head injury that may confound the patient's participation in the physical examination.

### Physical Examination

For cervical spine injury, the physical examination should include an inspection of the head, neck and upper torso. There is some debate whether signs of injury above the clavicles without associated neurological changes are associated with increased risk of cervical spine injury [9]. Injury above the clavicles with associated depressed neurological function is of great concern [10]. Palpation of the spine and paraspinal musculature should occur looking for

**Table 1** Two rules to guide imaging in patients who are at low risk for cervical spine injury

| |
|---|
| NEXUS |
| The National Emergency X-Radiology Utilization Study (NEXUS) Group developed and validated a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma [49]. The guidelines stipulate that radiography isn't required if patients satisfy all five of the following low-risk criteria |
| Absence of posterior midline cervical tenderness |
| Normal levels of alertness |
| No evidence of intoxication |
| No abnormal neurologic findings |
| No painful or distracting injuries |
| Canadian C-spine rule |
| The Canadian C-spine rules [12] use a series of three conditions to determine if further imaging is required |
| Radiography required in patients with the following criteria |
| Age 65 years or older |
| Dangerous mechanism of injury: fall from 1 m or five stairs, axial load to the head [i.e., diving, motor vehicle crash at high speeds (>100 km/h), motorized recreational vehicle accident, ejection, bicycle collision with a stationary object] |
| Paresthesia in the extremities |
| For patients with none of the high risk characteristics listed above, assess for any low-risk factor that allows for safe assessment of neck range of motion. Patients who do not fulfill all of the low-risk factors listed below are not suitable for range of motion testing and imaging should occur |
| Simple rear end motor vehicle accident which excludes: pushed into oncoming traffic, hit by bus or large truck, rollover, hit at high speed (> 100 km/h) |
| Sitting position |
| Ambulatory at any time |
| Delayed onset of neck pain |
| Absence of midline cervical spine tenderness |
| Test active range of motion. Image patients who are not able to rotate their neck actively 45° both left and right |

tenderness or deformity. A focused neurological examination is critical and should assess for symmetry in movement, sensation, proprioception and reflexes. Any suspected abnormality should trigger further evaluation or imaging. Signs of vertebrobasilar insufficiency could indicate traumatic vertebral artery injury.

## Diagnostic Studies

Two questions exist: (1) who needs imaging, and (2) what type of imaging should be obtained? It is currently standard of care in blunt trauma patients with neurologic deficit, significant localizing signs to the cervical spine, or other major distracting injuries to image the cervical spine (with some controversy existing for patients with distracting injuries) [11]. To assist care providers in patients who are at low risk for cervical spine injury, two rules have been developed to guide imaging. These rules include the NEXUS Low-risk Criteria and the Canadian C-spine rule (Table 1). These two methods of evaluation have been compared and the Canadian C-spine rules have a higher sensitivity and specificity than the NEXUS criteria, although both are currently accepted in clinical practice [12, 13].

Potential imaging modalities include cervical spine radiographs with or without flexion–extension, computed tomography (CT), and magnetic resonance imaging (MRI). While the decision to employ different imaging modalities is complex and beyond the scope of this manuscript, some general observations can be made.

Plain film radiographs are efficient and economical to obtain; a minimum series is an anteroposterior, lateral and open mouth odontoid view. To be adequate for evaluation, radiographs must show the bony anatomy from the occiput through the C7/T1 articulation. The latter may be difficult to view in patients who are heavy or have short necks. A swimmer's view radiograph (in which one shoulder is raised and the other dropped as if swimming a breast stroke) will usually shift the overlapping humeral heads to allow visualization of the cervicothoracic junction. Flexion/extension radiographs are rarely obtained in the acute clinical setting as splinting and spasm of the paraspinal muscles may make high quality films difficult to obtain and of unclear utility [14].

Most patients with major traumas are rapidly and efficiently imaged with modern CT, a modality which has a sensitivity and specificity of >99.9 % to detect clinically significant injury [15]. CT scanning is indicated in the evaluation of any patient with a fracture detected on plain radiographs as well as patients with inadequate or ambiguous radiographs and in those with a functionally ankylosed

spine (e.g., ankylosing spondylitis). Even with CT, subtle fractures may be missed in patients with ankylosed spines.

MRI is used in patients presenting with neurologic deficit. It can also be used in select patients to exclude ligamentous injury or detect subtle fractures in the face of a negative CT scan. Both CT and MRI may be combined with angiography to evaluate the vertebral arteries.

## Airway Management

Anesthesia personnel may be called to evaluate the patient with cervical spinal injury for initial airway management at presentation to the hospital or later, such as when operative treatment is required. The evaluation and techniques used to secure the airway are the same for both scenarios but the timeframe for the former may be emergent. As ATLS® has organized the overall approach to the trauma patient, a similar systematic approach to the airway provides a safe and expedient route to securing the airway.

In order to choose the appropriate technique to secure the airway, one must first start with an airway assessment. There is considerable controversy in the literature about the utility of the airway assessment in an emergent situation [16, 17] and for patients with cervical spine injury; many of the same issues are present. The patient's overall physiologic status may not allow for a detailed examination. The patient may be unconscious or not cooperative because of an altered mental status. Portions of the airway assessment may be difficult or impossible to perform because of injury or immobilization. Despite these limitations, information gathered as the specific situation allows may be tremendously helpful in airway management (Table 2).

The patient's specific data and clinical observations gleaned during the airway assessment along with other information (vital signs, other injuries, urgency for securing the airway, etc.) are synthesized and an airway plan formulated. An airway plan should include a primary technique for securing the airway as well as alternative techniques if the initial attempt fails. Choices for managing the airway can be grouped into the following categories.

### Mask Ventilation

Airway obstruction is a major cause of death immediately following trauma, and maintenance of a patent airway should remain a top priority of the bedside clinician as many cervical spinal cord injuries are traumatic [18, 19]. Airway obstruction may result from prolapse or interference of the soft palate, tongue, and/or epiglottis into the pharyngeal space due to loss of muscle tone. Obstruction can be made worse by other associated injuries or foreign objects [20, 21]. For patients without cervical spinal cord injury, simple maneuvers like the head tilt, chin lift and jaw thrust may relieve the obstruction and, combined with bag-mask ventilation, can provide a stable temporary airway [22, 23]. Immobilization devices such as cervical collars and halos can make it difficult to gain access to the face and may have to be loosed or removed to perform mask ventilation. In cadaver studies, it has been demonstrated that these simple maneuvers can cause movement of the cervical spine, potentially resulting in a secondary neurologic injury [24, 25]. For patients where mask ventilation is required, airway maneuvers should be avoided and use of airway adjuncts encouraged. Devices such as oral or nasal pharyngeal airways can assist in opening an obstructed airway but are not universally successful. The assumption

**Table 2** Airway exam in patients with known or suspected cervical spinal injury

| |
|---|
| Immobilization may present unique difficulties. For some assessments, the cervical collar must be opened and care to maintain cervical in-line stabilization with the assistance of an additional person may be reasonable |
| Assure that the patient's head and neck are properly immobilized |
| Note the size of the patient. Obesity may introduce additional problems for securing the airway |
| Determine level of consciousness. If conscious, engage the patient by asking simple questions (i.e., their name). This will provide information on mentation and their ability to protect their airway, at least in the short term. If the patient is unresponsive, the patient may be at risk for airway obstruction and aspiration and immediate steps to secure the airway initiated |
| Inspect the face, neck and chest for signs of injury or asymmetry. External injuries may indicate more serious internal injuries. Observe the respiratory pattern |
| Inspect the oral and pharyngeal cavity |
| Note limitations to intraoral distances. This may make introduction of an intubation device into the oral cavity difficult |
| Observe for loose or dislodged teeth or foreign bodies which may become obstacles to intubation or obstruct the airway and remove, if possible |
| Pooled blood, vomit or secretions may make visualization of the glottis difficult |
| A Mallampati score cannot be performed in a patient who is properly immobilized. Consider if there are any obstructions in the retropharynx which may hinder efforts to secure the airway |
| Observe the thyromental distance. Less than 6 cm indicates a potential difficult intubation via direct laryngoscopy |

that a patient will not obstruct or that mask ventilation will be successful is potentially dangerous, especially when a long-acting neuromuscular blocking agent is used in the course of a planned intubation. It is critical to assess for the risk of difficult mask ventilation. Patients reported to be a difficult mask ventilation include having a body mass index $\geq$30 kg/m$^2$, presence of a beard, edentulousness, male gender, age >57 years, and a Mallampati III or IV [26, 27].

## Direct Laryngoscopy

In non-injured patients undergoing intubation by direct laryngoscopy, the majority of cervical spinal motion has been shown radiographically to occur at the craniocervical junction at the level of C4 and above. There is minimal movement of the cervical spine with laryngoscope blade insertion. During laryngoscopy, most of the movement occurs with blade elevation and includes superior rotation of the occiput and C1 in the sagittal plane and mild inferior rotation of C3-C5. Additionally, with placement of the endotracheal tube there is superior rotation of occiput and C1 [28, 29]. In a cadaveric study of cervical spinal motion that occurred with an unstable C1-C2 segment, oral intubation caused a 1.66 mm reduction of the spinal cord space with 1–2 mm of distraction and 4–5° of angulation [30].

Manual in-line immobilization (MILI) is a maneuver that applies forces to the head and neck to offset any applied forces to the spine that occur during airway management. There should not be additional forces applied that result in axial traction, with the overall goal of keeping the head and neck in the same position during laryngoscopy. The efficacy for MILI in reducing secondary spinal cord injury during laryngoscopy is unclear and some have challenged its application [31]. The technique may be useful in reducing overall cervical spinal movements, but may have lesser effects at a midcervical point of injury. This point of injury has unrestricted movement in contrast to the caudal and cephalad cervical motion segments which are restricted by the torso and MILI application, respectively [32•]. MILI does impair visualization and may make tracheal intubation more difficult [33, 34]. Given the evidence, it is still recommended to apply MILI during laryngoscopy with the anterior cervical collar removed and without axial traction in an effort to prevent excessive cervical spinal cord movement.

## Indirect Laryngoscopy

Intubating techniques that avoid having to bring anatomic structures in-line to allow for glottic visualization have a potential advantage in immobilized cervical spine injured patients. Removal of the cervical collar may not be necessary and immobilization of the cervical spine may be continued during intubation. If intubation in an awake patient is performed, the risk of airway obstruction may be reduced. Additionally, a post-intubation neurological examination may be performed to confirm no secondary injury occurred during the procedure. Devices in this category include the flexible fiberoptic bronchoscope as well as videolaryngoscopes.

Historically the flexible fiberoptic bronchoscope has been the choice for patients presenting for elective cervical spine injury [35]. The success rate of flexible fiberoptic bronchoscopy in trauma patients has been reported as 83.3 %; however, it is unclear how many patients had cervical spinal injury and would be expected to be highly patient- and proceduralist-dependent [36]. Cadaveric studies have demonstrated decreased movement with this technique [25], but a clear clinical benefit has not been demonstrated; some have argued that in inexperienced hands, its use might be detrimental [37•].

The use of a videolaryngoscope for cervical spine injury patients continues to increase, and clinical studies continue to show promise as a viable technique in this patient population. In all patients, videolaryngoscopy has been demonstrated to provide an improved Cormack–Lehane grade view over direct laryngoscopy; however, this does not necessarily translate to a higher success rate or decreased time to intubation [38–40]. Because there is potentially less force and soft tissue displacement with the use of this device, there may be less cervical spine motion; this is a great benefit in the cervical spine injury patient population [40–42].

Indirect laryngoscopy, which may include flexible fiberoptic bronchoscopes and videolaryngoscopes, continues to be a safe and successful choice for intubation of the cervical spine injury patients whether electively or emergently.

## Extraglottic Airway

Extraglottic airways refer to devices that ventilate above the vocal cords and include devices like the laryngeal mask airway (LMA), intubating laryngeal airway, Combitube and the newer King® airway (Kingsystems; Nobelsville, IN). These devices may be seated below, at, or above the glottis and come in many shapes and sizes. A detailed description about each device is available [43]. Aside from the intubating LMA, none cannulate the trachea explicitly as part of the normal use of the device, although this may be a secondary option for some. Advantages of these devices are that they can be quickly and blindly inserted and work by stenting open the airway. All have pharyngeal cuffs that provide a seal between the device and the surrounding tissue. Depending on how much air is instilled into the device, the cuffs may exert a pressure that theoretically could displace the injured cervical spine [44, 45]. These devices function best when used with a spontaneously breathing patient [46], and the primary role in patients with

cervical spine injury may be as a primary device for those with limited airway management skills or as a rescue device [47].

### Surgical Airway

Historically, a surgical airway or cricothyrotomy was the preferred route for securing the airway over oral tracheal intubation [32•]. Currently, it is felt to be a rescue technique when other forms of airway management have failed, although it may be a first line airway management technique if necessitated by other concurrent injuries such as facial trauma. One study looked at cricothyrotomy in 13 cadavers with a C5-C6 injury to measure axial distraction via fluoroscopy. They found that 1–2 mm of anterior–posterior displacement occurred with <1 mm of axial compression during the procedure [48]. The clinical relevance of this is unclear; thus, if a patient with a cervical spine injury requires a surgical airway, there should be no hesitation to do so.

## Conclusion

Cervical spine injuries exist along a spectrum from minor fractures requiring little more than immobilization to devastating and potentially fatal injuries associated with neurologic compromise. Attention to head positioning and stabilization during the initial evaluation and airway management is important in the care of these patients in order to minimize the risk of secondary neurologic insult. Awareness that these patients are at risk for airway obstruction is critical. A systemic approach and development of an individualized airway plan is necessary for optimal management of patients with cervical spine injury.

**Disclosures** Daniel A. Diedrich, Peter S. Rose, and Daniel R. Brown declare that they have no conflict of interest.

**Compliance with Ethics Guidelines** This article does not contain any studies with human or animal subjects performed by any of the authors.

## References

Papers of particular interest, published recently, have been highlighted as:
- Of importance


1. Heller JG, Pedlow FX Jr, Gill SS. Anatomy of the cervical spine. In: Clark CR, Benzel BC, Cervical Spine Research Society, editors. The cervical spine, 4th ed. Philadelphia: Lippincott Williams & Wilkins; 2005. p. 3–37.
2. Goel VK, Clark CR, Gallaes K, Liu YK. Moment–rotation relationships of the ligamentous occipito-atlanto-axial complex. J Biomech. 1988;21:673–80.
3. Panjabi MM, Duranceau JS, Oxland TR, Bowen CE. Multidirectional instabilities of traumatic cervical spine injuries in a porcine model. Spine. 1989;14:1111–5.
4. White AA, Panjabi MM. Clinical biomechanics of the spine. 2nd ed. Philadelphia: Lippincott; 1990.
5. Inaba K, Barmparas G, Ibrahim D, et al. Clinical examination is highly sensitive for detecting clinically significant spinal injuries after gunshot wounds. J Trauma. 2011;71:523–7.
6. Grossman MD, Reilly PM, Gillett T, Gillett D. National survey of the incidence of cervical spine injury and approach to cervical spine clearance in U.S. trauma centers. J Trauma. 1999;47:684–90.
7. Tay B, Eismont F: Cervical spine fractures and dislocations. In: Fardon DF, Garfin SR. Rosemont, IL, editors. Orthopaedic knowledge update. Spine 2. Rosemont: American Academy of Orthopaedic Surgeons; 2002. p. 247–62.
8. American College of Surgeons Committee on Trauma. ATLS: Advanced trauma life support for doctors (Student Course Manual). 8th ed. Chicago: American College of Surgeons; 2008 (ISBN-10: 1880696312).
9. Hackl W, Hausberger K, Sailer R, Ulmer H, Gassner R. Prevalence of cervical spine injuries in patients with facial trauma. Oral Surg Oral Med Oral Pathol Oral Radiol Endodontol. 2001;92:370–6.
10. Williams J, Jehle D, Cottington E, Shufflebarger C. Head, facial, and clavicular trauma as a predictor of cervical-spine injury. Ann Emerg Med. 1992;21:719–22.
11. Rose MK, Rosal LM, Gonzalez RP, et al. Clinical clearance of the cervical spine in patients with distracting injuries: it is time to dispel the myth. J Trauma Acute Care Surg. 2012;73:498–502.
12. Stiell IG, Clement CM, McKnight RD, et al. The Canadian C-spine rule versus the NEXUS low-risk criteria in patients with trauma. N Engl J Med. 2003;349:2510–8.
13. Duane TM, Dechert T, Wolfe LG, et al. Clinical examination and its reliability in identifying cervical spine fractures. J Trauma. 2007;62:1405–8.
14. McCracken B, Klineberg E, Pickard B, Wisner DH. Flexion and extension radiographic evaluation for the clearance of potential cervical spine injures in trauma patients. Eur Spine J. 2004. doi: 10.1007/s00586-012-2598-z.
15. Panczykowski DM, Tomycz ND, Okonkwo DO. Comparative effectiveness of using computed tomography alone to exclude cervical spine injuries in obtunded or intubated patients: meta-analysis of 14,327 patients with blunt trauma. J Neurosurg. 2011;115:541–9.
16. Levitan RM, Everett WW, Ochroch EA. Limitations of difficult airway prediction in patients intubated in the emergency department. Ann Emerg Med. 2004;44:307–13.
17. Bair AE, Caravelli R, Tyler K, Laurin EG. Feasibility of the preoperative Mallampati airway assessment in emergency department patients. J Emerg Med. 2010;38:677–80.
18. Esposito TJ, Sanddal ND, Hansen JD, Reynolds S. Analysis of preventable trauma deaths and inappropriate trauma care in a rural state. J Trauma. 1995;39:955–62.
19. Hussain LM, Redmond AD. Are pre-hospital deaths from accidental injury preventable? BMJ. 1994;308:1077–80.
20. Shorten GD, Opie NJ, Graziotti P, et al. Assessment of upper airway anatomy in awake, sedated and anaesthetised patients using magnetic resonance imaging. Anaesth Intensive Care. 1994;22:165–9.
21. Mathru M, Esch O, Lang J, et al. Magnetic resonance imaging of the upper airway. Effects of propofol anesthesia and nasal continuous positive airway pressure in humans. Anesthesiology. 1996;84:273–9.

22. Guildner CW. Resuscitation-opening the airway. A comparative study of techniques for opening an airway obstructed by the tongue. JACEP. 1976;5(8):588–90.
23. Uzun L, Ugur MB, Altunkaya H, et al. Effectiveness of the jaw-thrust maneuver in opening the airway: a flexible fiberoptic endoscopic study. ORL J Otorhinolaryngol Relat Spec. 2005;67: 39–44.
24. Hauswald M, Sklar DP, Tandberg D, Garcia JF. Cervical spine movement during airway management: cinefluoroscopic appraisal in human cadavers. Am J Emerg Med. 1991;9:535–8.
25. Brimacombe J, Keller C, Kunzel KH, et al. Cervical spine motion during airway management: a cinefluoroscopic study of the posteriorly destabilized third cervical vertebrae in human cadavers. Anesth Analg. 2000;91:1274–8.
26. Kheterpal S, Han R, Tremper KK, et al. Incidence and predictors of difficult and impossible mask ventilation. Anesthesiology. 2006;105:885–91.
27. Conlon NP, Sullivan P, Herbison PG, et al. The effect of leaving dentures in place on bag-mask ventilation at induction of general anesthesia. Anesth Analg. 2007;105:370–3.
28. Horton WA, Fahy L, Charters P. Disposition of cervical vertebrae, atlanto-axial joint, hyoid and mandible during X-ray laryngoscopy. Br J Anaesth. 1989;63:435–8.
29. Sawin PD, Todd MM, Traynelis VC, et al. Cervical spine motion with direct laryngoscopy and orotracheal intubation. An in vivo cinefluoroscopic study of subjects without cervical abnormality. Anesthesiology. 1996;85:26–36.
30. Donaldson WF 3rd, Heil BV, Donaldson VP, Silvaggio VJ. The effect of airway maneuvers on the unstable C1-C2 segment. A cadaver study. Spine. 1997;22:1215–8.
31. Manoach S, Paladino L. Manual in-line stabilization for acute airway management of suspected cervical spine injury: historical review and current questions. Ann Emerg Med. 2007;50:236–45.
32. • Crosby ET. Airway management in adults after cervical spine trauma. *Anesthesiology.* 2006;104:1293–1318. *This reference provides a thorough review of the topic of airway management in cervical spine injury.*
33. Nolan JP, Wilson ME. Orotracheal intubation in patients with potential cervical spine injuries. An indication for the gum elastic bougie. Anaesthesia. 1993;48:630–3.
34. Thiboutot F, Nicole PC, Trepanier CA, et al. Effect of manual in-line stabilization of the cervical spine in adults on the rate of difficult orotracheal intubation by direct laryngoscopy: a randomized controlled trial. Can J Anaesth. 2009;56:412–8.
35. Fuchs G, Schwarz G, Baumgartner A, et al. Fiberoptic intubation in 327 neurosurgical patients with lesions of the cervical spine. J Neurosurg Anesthesiol. 1999;11:11–6.
36. Dunham CM, Barraco RD, Clark DE, et al. Guidelines for emergency tracheal intubation immediately after traumatic injury. J Trauma. 2003;55:162–79.
37. • Langford RA, Leslie K. Awake fibreoptic intubation in neurosurgery. *J Clin Neurosci.* 2009;16:366–72. *Good review of the technique with application beyond the narrow patient population.*
38. Stroumpoulis K, Pagoulatou A, Violari M, et al. Videolaryngoscopy in the management of the difficult airway: a comparison with the Macintosh blade. Eur J Anaesthesiol. 2009;26:218–22.
39. Kaplan MB, Hagberg CA, Ward DS, et al. Comparison of direct and video-assisted views of the larynx during routine intubation. J Clin Anesth. 2006;18:357–62.
40. Malik MA, Maharaj CH, Harte BH, Laffey JG. Comparison of Macintosh, Truview EVO2®, Glidescope®, and Airwayscope® laryngoscope use in patients with cervical spine immobilization. Br J Anaesth. 2008;101:723–30.
41. Maruyama K, Yamada T, Kawakami R, et al. Upper cervical spine movement during intubation: fluoroscopic comparison of the AirWay Scope, McCoy laryngoscope, and Macintosh laryngoscope. Br J Anaesth. 2008;100:120–4.
42. Carassiti M, Zanzonico R, Cecchini S, et al. Force and pressure distribution using Macintosh and GlideScope laryngoscopes in normal and difficult airways: a manikin study. Br J Anaesth. 2012;108:146–51.
43. Luba K, Cutter TW. Supraglottic airway devices in the ambulatory setting. Anesthesiol Clin. 2010;28:295–314.
44. Keller C, Brimacombe J, Keller K. Pressures exerted against the cervical vertebrae by the standard and intubating laryngeal mask airways: a randomized, controlled, cross-over study in fresh cadavers. Anesth Analg. 1999;89:1296–300.
45. Kihara S, Watanabe S, Brimacombe J, et al. Segmental cervical spine movement with the intubating laryngeal mask during manual in-line stabilization in patients with cervical pathology undergoing cervical spine surgery. Anesth Analg. 2000;91:195–200.
46. Hagberg CA, Benumof J. Benumof's airway management: principles and practice. Philadelphia: Mosby Elsevier; 2007.
47. Mayglothling J, Duane TM, Gibbs M, et al. Emergency tracheal intubation immediately following traumatic injury: an Eastern Association for the Surgery of Trauma practice management guideline. J Trauma Acute Care Surg. 2012;73:S333–40.
48. Gerling MC, Davis DP, Hamilton RS, et al. Effect of surgical cricothyrotomy on the unstable cervical spine in a cadaver model of intubation. J Emerg Med. 2001;20:1–5.
49. Hoffman JR, Mower WR, Wolfson AB, et al. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. N Engl J Med. 2000;343:94–9.