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Airway Management in the Patient with Cervical Spine Instability

By Arnaud Robitaille, MD

Securing the airway of a patient with a potentially unstable cervical spine (C-spine) is a complex and challenging task. To perform this both safely and efficiently, the anesthesiologist should know C-spine anatomy, biomechanics, and the assessment of stability both clinically and radiologically. In addition, an appreciation of the efficacy, benefits, and risks of stabilization maneuvers is required to understand the impact of different airway-management techniques on the spine and on clinical outcomes. This issue of *Anesthesiology Rounds* reviews the current knowledge that is essential for airway management in the face of potential C-spine instability, and underlines areas of uncertainty and the limitations in the literature.

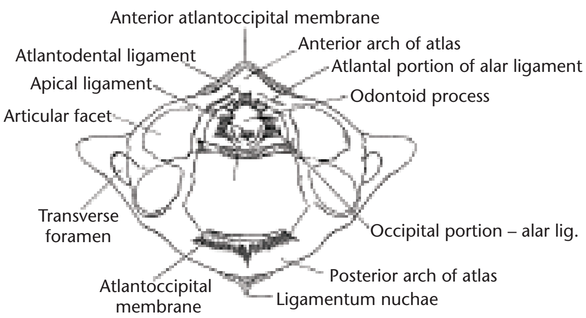
C-SPINE ANATOMY AND BIOMECHANICS

The C-spine is composed of the skull base and 7 cervical vertebrae (Figures 1 and 2). The lower "subaxial" portion (C3 to C7) comprises 5 vertebrae that are anatomically similar to their thoracic and lumbar counterparts, except for the presence of bilateral transverse foramina through which ascend the vertebral arteries. The upper "axial" portion, however, has 3 bony elements with distinct anatomical characteristics: the skull base (occiput); the atlas (C1) that has a ring-like shape with no vertebral body and no spinous process; and the axis (C2), which is characterized by its odontoid process (or dens) protruding upward from the vertebral body into the ring of C1.

Vertebral discs, facet joints, paravertebral muscles, and numerous ligaments stabilize the bony structure of the C-spine. The transverse ligament tethers the odontoid process to the posterior surface of the C1 anterior arch. The apical and alar ligaments extend from the odontoid process to the anterior margins of the foramen magnum on the skull base. The anterior and posterior spinal ligaments ascend respectively on the anterior and posterior surfaces of the vertebral bodies. The ligamentum flavum connects adjacent lamina. Finally, the inter- and supraspinal ligaments join the spinous processes together. Ascending in the spinal canal, the spinal cord is separated from the bony and ligamentous elements by the fluid-filled cerebrospinal subarachnoid space.

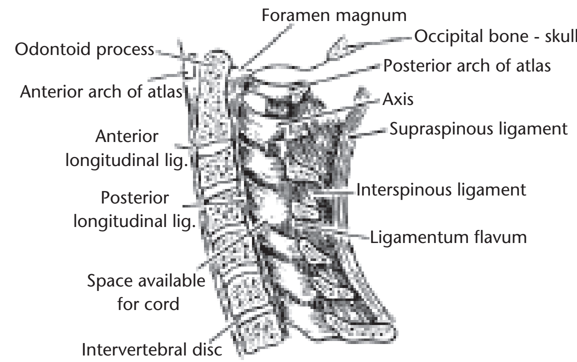
The C-spine supports movement in 3 axes (flexion/extension, rotation, and lateral bending), but airway manipulations involve almost exclusively flexion and extension. Motion is not distributed uniformly in the C-spine:[1] occiput-C1 allows 15°-20° of extension, but only about 5° of flexion, while C1-C2, which is most important in axial rotation, allows about 10° of both flexion and extension; approximately 65° of further flexion/extension is gained from the subaxial C-spine, with most of the motion attributable to the caudal segments.

FIGURE 1: Atlas and odontoid process



Figures 1 and 2 are from: White, AA III, Panjab, MM. *Clinical Biomechanics of the Spine.* Philadelphia, PA: J.B. Lippincott;1978. Used with permission.

FIGURE 2: The ligaments of the lower cervical spine, sagittal section



ASSESSING C-SPINE STABILITY

Establishing whether the C-spine of a patient is stable, often referred to as "clearing the C-spine," is a complicated task that has important consequences for the patient and from a medico-legal point of view. Since most of the literature is derived from trauma settings, this discussion is restricted to trauma patients. Nevertheless, many of the same principles can be applied to patients who present with other pathologies. A medical history and physical examination form the basis of the initial stratification of patients, who present with potential C-spine instability, into either "asymptomatic" or "symptomatic," and determine whether radiological studies are indicated.

To be considered asymptomatic, patients should meet the criteria established through large, multicentre studies involving thousands of trauma patients.[2,3] In these patients, the C-spine can be cleared without further radiological assessment, avoiding unnecessary radiation to the patient and saving considerable resources. The National Emergency X-Radiography Study Group (NEXUS) validated one commonly used set of criteria. According to their study,[2] an adult blunt-trauma patient who presents no midline cervical tenderness, no focal neurological deficit, normal alertness, no intoxication, and no painful distracting injury, has a 99.9% chance of no clinically significant C-spine injury. In this subgroup of patients, guidelines agree that the C-spine can be cleared without specific imaging.[4-6]

In symptomatic patients, imaging is indicated before clearing the C-spine. Initially, a 3-view trauma series is usually performed; this consists of a cross-table lateral view (visualizing the entire C-spine, from the base of the occiput to the upper part of T1), an open-mouth odontoid view, and an anteroposterior view. However, since this series often inadequately visualizes the craniocervical and cervicothoracic spine (where most injuries tend to occur) and is prone to misinterpretation, particularly by non-radiologists, a normal 3-view trauma series is *not* considered sufficient to rule out C-spine injury in the symptomatic patient.[5-7] Systematically, a thin-section computed tomographic (CT) examination that includes both sagittal and coronal multiplanar reconstructed images should be added.[5-7] Plain-film and CT scanning must be considered complementary studies in the symptomatic patient, since they often detect different patterns of injury. In combination, they have consistently demonstrated a negative predictive value of 99%-100% and are considered by some as sufficient to clear the C-spine.[8,9]

The role of magnetic resonance imaging (MRI) is clearly established in evaluating spinal-cord injury and, therefore, trauma patients in whom cord injury is suggested by clinical presentation or imaging should undergo MRI if possible.[5,6] In a routine evaluation, however, the addition of MRI to plain-film and CT scanning in the symptomatic trauma patient is more controversial. The advantage of MRI is its ability to directly demonstrate ligamentous pathology, which could be missed by plain-film and CT, especially if it is not associated with fractures. However, MRI is an extremely sensitive study, and the significance of the soft-tissue abnormalities it reveals is often unknown. In addition, routine use of MRI would increase costs and expose patients to risks, such as during transfer to the MRI suite, or from prolonged immobilization (either while waiting for MRI to be feasible, or during prolonged analysis of an image of uncertain significance in a patient who cannot be examined neurologically). Since the risk/benefit ratio of routine MRI remains unclear, guidelines do not recommend its systematic addition to the radiological assessment of symptomatic trauma patients. Rather, MRI is confined to patients experiencing symptoms referable to spinal-cord injury,[5,6] or listed as an "option" to consider when investigating the C-spine of a symptomatic trauma patient, recognizing the real possibility of false-positive findings.[7]

Finally, dynamic fluoroscopy, which involves flexing and extending the C-spine under real-time lateral fluoroscopy, has also been proposed as a complement to plain film and CT scanning. Dynamic fluoroscopy is used to search for instability related to ligamentous injury. In addition to obvious concerns regarding manipulation of the C-spine in obtunded patients, doubts have been raised about the ability of this modality to change patient management.[10] Guidelines reflect disagreement among experts about the role of dynamic fluoroscopy: some recommend its use in obtunded patients, in addition to plain films and CT;[5] some place it as an option equivalent to MRI;[7] while others consider it as a fourth-line study to be considered only in equivocal cases.[6]

IMMOBILIZATION

Anesthesiologists caring for patients with a potentially injured C-spine will most often need to secure the airway before the C-spine has been properly cleared, or before it has been surgically stabilized, in the case of injury. In a trauma context, typically, these patients will have their C-spine immobilized using a rigid cervical collar, sandbags, tape, and a backboard, or a variation thereof, since this combination has been shown to produce the greatest restriction of movement.[11] Although intuitively appealing and widely recommended,[12,13] to date, the practice of immobilizing a potentially injured C-spine to prevent secondary neurological injury has not been demonstrated to improve patient outcome.[14] Furthermore, immobilization also involves risk: airway obstruction can occur and, if immobilization becomes prolonged, problems such as pressure sores, difficult intravenous access and nursing care, and increased nosocomial infections tend to develop. Despite these uncertainties, it remains unlikely that immobilization will be properly evaluated by randomized, controlled trials, and it will remain part of clinical practice for the foreseeable future.

For the anesthesiologist, immobilization during airway management is of particular interest. The cervical collar-sandbag-tape-backboard combination hinders airway management independently of its immobilizing effect on the C-spine by severely limiting mouth opening[15] and restricting access to the patient's neck; therefore, it is currently recommended to remove the anterior part of the cervical collar with manual in-line stabilization (MILS) of the C-spine.[12] MILS can be applied either from the head of the bed by an assistant who grasps the mastoid processes with his fingertips and cups the occiput in his hands, or from the side of the bed by grasping the occiput and cupping the mastoids. The person providing MILS should apply only the amount of force necessary to counteract the forces exerted by the laryngoscopist, without applying axial traction. Nevertheless, MILS remains controversial, primarily because its effect on patient outcome has not been properly studied, and because its ability to decrease cervical motion during airway management has been challenged.[16] It has been clearly established, however, that MILS significantly increases Cormack-Lehane grade with direct laryngoscopy (DL),[17] potentially complicating airway management in patients who can often be particularly vulnerable to hypoxia.

IMPACT OF DIFFERENT AIRWAY TECHNIQUES

Traditionally, much emphasis has been placed on the risk of secondary neurological injury from excessive C-spine motion during airway management. The movement generated by different airway techniques has been extensively documented in the literature; for those requiring more than this partial review, thorough reviews are available elsewhere.[9]

In normal subjects under general anesthesia without MILS, endotracheal intubation with DL induces extension at each individual vertebral segment.[18] Most motion occurs in the axial spine, while the subaxial spine down to C5 (the last segment visualized with fluoroscopy in many studies) moves only very little. Considered as a whole, the C-spine undergoes extension of its rostral portion, but flexion of its caudal portion that is "anchored" by the thorax and pivots around the cervicothoracic junction during laryngoscopy. Amplitude of movement increases throughout the procedure, reaching its maximum during the passage of the endotracheal tube.

Most studies in the literature do not consider the effects of airway techniques individually; instead, they compare them, often using DL as a reference. Studies have compared the effect of basic airway maneuvers such as chin lift, jaw thrust, and mask ventilation with that of DL; although some older studies suggested that these basic airway maneuvers induced greater C-spine movement than DL,[19] more recent work with an improved methodology have indicated the motion is either comparable[20] or inferior.[21] Similarly, the effect of cricoid pressure has been found to be very modest,[22] albeit in the intact cervical spine.

The impact of 4 airway techniques (laryngeal mask airway [LMA] insertion, nasal fibreoptic intubation, tracheoesophageal Combitube® placement, and fibreoptic intubation via an intubating LMA), in addition to DL, was studied by Brimacombe et al,[20] using a cadaver model with posterior C3 instability and undergoing MILS. They found that only nasal intubation over a fibreoptic bronchoscope produced insignificant movement, and that insertion of a Combitube® produced the most movement.

Recently, Turkstra et al[21] compared the effect of DL, Trachlight® lighted intubating stylet, and GlideScope® videolaryngoscopy in normal subjects under general anesthesia with C-spine stabilization. While Trachlight® reduced the movement by almost one-half compared with DL, it offered no clinically significant reduction in movement. This finding was recently confirmed by Robitaille et al.[23]

With new airway devices constantly being introduced into clinical practice, similar studies will continue to expand the literature. Nevertheless, it should be recognized that these studies have very important limitations; most notably, there is no clearly established threshold defining dangerous C-spine movement.[24] Therefore, it can be very difficult to determine whether a statistically significant difference between 2 techniques is actually clinically significant. In addition, a significant movement in one patient may not cause harm in another, since many other factors (eg, hemodynamic instability, tissue edema) may compound the mechanical effect of C-spine motion on damaged neurological tissue.[25] Furthermore, most studies are performed on subjects with an intact C-spine or on cadavers with one standardized type of injury; as a result, generalizing findings from these studies to the heterogeneous population of real-life patients with C-spine injury remains difficult, and it is also difficult to compare results from different studies using various injury models or different methodologies.

A further limitation inherent to this literature is the exclusive focus on quantifying C-spine movement without considering the broader question of clinical outcome. Indeed, it is prudent to minimize C-spine motion to prevent secondary neurological injury, particularly when the level of acceptable movement is unknown and may even vary from patient to patient. Nevertheless, the most important question for the clinician is how airway management affects patient outcome when C-spine instability is present? Since it is difficult to conduct methodologically strong studies dealing with this question, answers must be sought from case reports and case series, with their inherent limitations.

Although airway management in patients with C-spine instability is a relatively common clinical occurrence, the actual number of cases indicating that management caused neurological deterioration is small and, in many of those cases, the causal link between them is tenuous.[25] Furthermore, many medium-sized case series in patients with C-spine instability undergoing airway management (often DL under general anesthesia) reported no neurological deterioration after intubation.[26,27] These studies may suffer from reporting bias and lack adequate power to detect rare events; however, together they suggest that the risk of causing secondary neurological damage when securing the airway, although not absent, may be smaller than originally perceived.[25]

Such an assessment of the literature should encourage the anesthesiologist to broaden his/her perspective when approaching a patient with potential C-spine instability. While minimizing C-spine movement remains important, other objectives such as rapidly and effectively securing the airway may also need consideration in certain clinical situations. Different airway devices offer different advantages, and the one that is most appropriate will often depend on the specific clinical situation, for example:

- the fibreoptic bronchoscope provides significant C-spine stability in the cooperative and adequately prepared patient, but is often ill-suited for the trauma context
- DL induces slightly more C-spine movement, but offers convenience, rapidity, and relative immunity to the presence of secretions or blood in the airway

- videolaryngoscopy offers better glottic visualization than DL in the presence of MILS,[23] but generally takes more time to accomplish.[21]

SUMMARY AND CONCLUSIONS

Optimally managing the airway in the face of potential C-spine instability requires knowledge of the basic C-spine anatomy and an understanding of how to assess stability, how to immobilize the C-spine, and how to select an appropriate airway technique. In the area of clinical evaluation and imaging, strong recommendations can be made based on evidence-based guidelines:

– medical history and physical examination are sufficient to clear the C-spine in asymptomatic adult patients presenting no midline cervical tenderness, no focal neurological deficit, normal alertness, no intoxication, and no painful distracting injury

– minimally, a 3-view trauma series plus a thin-section CT scan are mandatory in symptomatic patients.

Recommendations concerning immobilization are consistent, but it should be recognized that they rely on scant evidence and all the recommended techniques have drawbacks:

- a rigid cervical collar, sandbags, tape and a backboard, or a variation thereof, should be used to immobilize the C-spine of trauma patients, and the C-spine should be cleared rapidly to avoid the complications of prolonged immobilization
- standard immobilization techniques severely impair airway management, thus the anterior portion of the hard collar should be removed and MILS applied when securing the airway, although DL will likely be more difficult in this context.

No guidelines exist regarding the choice of airway management technique. Based on case reports and case series, currently employed techniques appear safer than previously thought. Minimizing C-spine motion remains an important objective; nevertheless, other goals mandated by specific clinical situations should not be neglected, such as rapidly and effectively securing the airway to prevent hypoxia. Different techniques offer different benefits and limitations; therefore, selection should be based on the specific clinical situation and on the experience of the practitioner.

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Abstracts of Interest

Predictors of difficult intubation in patients with cervical spine limitations

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BACKGROUND: Cervical spine function is of paramount importance to the management of the airway. What has not been reported in the literature is a systematic analysis of airway management in patients with cervical spine limitation (CSL) compared with their normal counterparts or a predictive model of difficult intubation (DI) in patients with CSL.

METHODS: We reviewed the electronic charts of 14,053 patients and identified those with CSL based on the preoperative airway evaluation. We then compared various airway parameters in patients with CSL to those without CSL and further assessed risk factors for DI in patients with CSL. We develop a predictive model on the basis of multivariate analysis of such risk factors.

RESULTS: Of the cohort studied, 1145 or 8.1% of patients were documented as having some form of CSL, with an average age of 60. In the <60 population, CSL was associated with a statistically significant increase in difficult and impossible mask ventilation, difficult laryngoscopy, and DI. In the population ≥60 years old, CSL was associated with a statistically significant increase in difficult laryngoscopy and DI. There were no significant differences in mask ventilation between normal and CSL patients in the population ≥60. Multivariate modeling revealed age ≥48, Mallampati 3 or 4, and thyromental distance <6 cm as independent preoperative risk factors of DI in patients with CSL. A predictive model is developed on the basis of these findings.

CONCLUSIONS: Limitations of cervical spine mobility are relatively common and increase the incidence of difficulty throughout the spectrum of airway management. DI should be anticipated in CSL patients who are ≥48 years old, have a Mallampati class 3 or 4, and a thyromental distance of <6 cm.

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Management of the airway in patients undergoing cervical spine surgery

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The perioperative management of the airway in patients with cervical spine disease requires careful consideration. In an observational prospective cohort study, we assessed the preoperative factors that may have influenced the anesthesiologists' choice for the technique of intubation and the incidence of postoperative airway complications. We recorded information from 327 patients: mean (±SD) age 51±15 year, 138 females and 189 males, for anterior surgical approach (n=195) and posterior (n=132). The technique of intubation used was awake fiberoptic bronchoscopy (FOB) in 39% (n=128), asleep FOB 32% (n=103), asleep laryngoscopy 22% (n=72), and other asleep 7% (n=24). Awake FOB was predominately chosen for intubating patients with myelopathy (45%), unstable/fractured spine (73%), and spinal stenosis (55%) but patients with radiculopathy had more asleep FOB (49%) (*P*<0.001). There was no association between method of intubation and postoperative airway complications. Acute postoperative airway obstruction occurred in 4 (1.2%) patients requiring reintubation. The technique of management of the airway for cervical spine surgery varied considerably among the anesthesiologists, although the choice was not associated with postoperative airway complications.

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