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C-Spine Injury

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CONTENTS

CERVICAL SPINE INJURY – AIRWAY MANAGEMENT FOR THE BROKEN NECK

Introduction

The potentially unstable neck is a fairly frequent source of discontent for anaesthesiologists. There is concern that our airway interventions may provoke or worsen spinal cord injury. Is this justified?

Anaesthetists do chip and dislodge teeth, cause the odd pneumothorax and do other minor damage to the oral cavity but can we and/or do we aggravate neck injuries during airway interventions?

The brunt of this presentation will focus on the trauma scenario in the adult population. Much of the evidence is old and plagued with the usual uncertainties but still deserves pondering.

Given that we regularly manipulate the neck we should probably be aware of the spectrum of cervical spine injury and particularly, which injuries are unstable.

Outline:
Normal anatomy of the cervical spine
Stability and instability
Injuries of the cervical spine
Spinal movement during airway interventions
Cervical spine trauma – epidemiology, clinical characteristics, assessment, 2ndary neurological injury. clinical care, airway management options

The Adult Cervical Spine:
Composed of 7 vertebrae, the upper 2 (atlas and axis) highly specialized and the lower 5 more anatomically typical but for the foramen transversarium allowing passage of the vertebral artery.

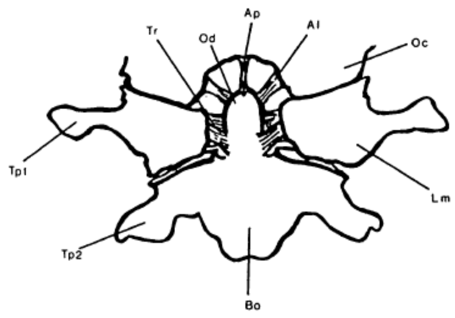


FIGURE 1 Occipitoatlantoaxial complex. Coronal section, anterior arch of atlas removed. Ap – apical ligament; Al – alar ligament; Oc – occipital condyle, skull; Lm – lateral mass, atlas; Bo – body, axis; Tp2 – transverse process, axis; Tp1 – transverse process, atlas; Tr – transverse ligament; Od – odontoid process, axis.

The atlas has no body and comprises anterior and posterior arches joined by lateral masses. The axis has a large vertical projection- the odontoid process or dens which is the embryological remnant of the body of C1

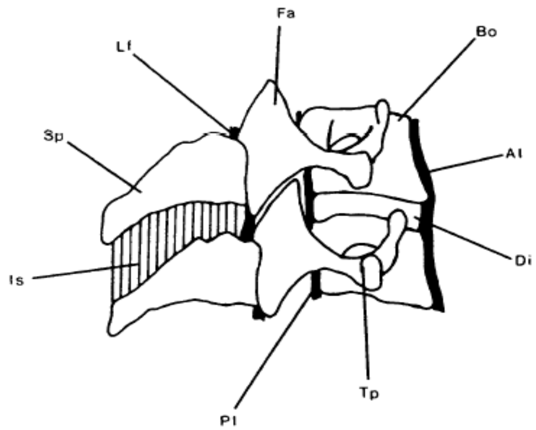


FIGURE 2 Lower cervical spine. Lateral view. Fa – articular facet; Bo – vertebral body; Al – anterior longitudinal ligament; Di – intervertebral disc; Tp – transverse process; Pl –posterior longitudinal ligament; Is – interspinous ligament; Sp – spinous process; Lf – ligamentum flavum.

STABILITY, INJURY, AND INSTABILITY

Stability is the capacity of the spine to withstand physiologic loading and positioning without neurologic injury, deformity, or pain.

Movement and Stability of the Upper Cervical Spine (C1-2)

Flexion– extension occurs in the upper cervical spine at both the atlanto-occipital and atlantoaxial articulations, and a combined 24° of motion may be achieved.

Several ligaments contribute to the stability of the upper complex: the *transverse*, *apical*, and *alar ligaments* as well as the superior terminations of the *anterior* and *posterior longitudinal ligaments*

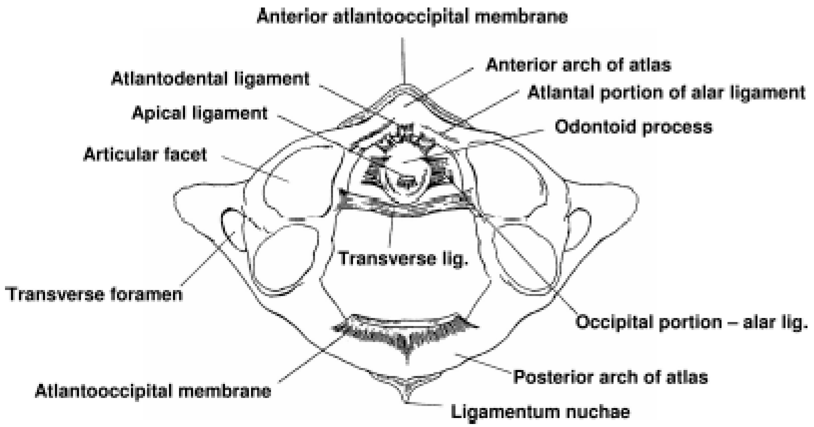


Fig. 1. Ligaments of the atlantoaxial joint. View is from above, with the skull removed.

The transverse ligament normally allows no more than 3mm of anteroposterior translation between the *dens* and the anterior arch of the *atlas*. This *atlas–dens interval* (ADI) may be measured on lateral neck radiographs. If all the ligaments have been disrupted, 10 mm or more of displacement may be seen. Destruction of these ligaments is also a common consequence of severe and long-standing rheumatoid arthritis.

Steele's Rule of Thirds:

The area of the spinal canal at Cl may be divided into one third odontoid, one third cord, and one third “space.” The latter two thirds comprises the space available for the cord (SAC) which is the diameter of the spinal canal measured in the anteroposterior plane at the Cl level, that is not occupied by the *odontoid process*. The canal of the atlas is about 3 cm in its AP diameter.

The spinal cord, odontoid process, and free space for cord are each about 1 cm in diameter.The one third space allows for some encroachment on the spinal lumen without cord compromise but anterior displacement of the atlas (or posterior displacement of the dens) that exceeds one centimeter may jeopardize the adjacent segment of the spinal cord.

The cord occupies a greater proportion of the available SAC in the subaxial spine (at the C6 level, approximately 75%).

Movement and Stability of the Lower Cervical Spine(C3-7)

A further 66° of flexion–extension may be achieved in the lower cervical spine, with the most motion occurring at C5–C7 segments. This range of motion will decrease with age but this usually does not have a significant impact on the ease of direct laryngoscopy.

Contributing to stability include, from anterior to posterior, the *anterior longitudinal ligament*, the *intervertebral discs*, the posterior longitudinal ligament, the *facet joints* with their capsular ligaments and the *intertransverse ligaments*, the *interspinous ligament*, and the *supraspinous ligaments*

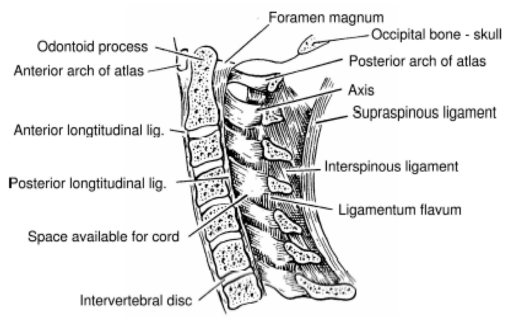


Fig. 2. The ligaments of the lower cervical spine, sagittal section.

The 2 (or 3) column concept of the spinal column

The posterior longitudinal ligament and the structures anterior to it are grouped as the *anterior elements* or *anterior column* (fig. 3). The *posterior elements* or *posterior column* are those grouped behind the posterior ligament. Some define a third column – the middle column as the posterior third of the vertebral body. Disruption of 2 or more columns results in instability.

Motion segments are defined as two adjacent vertebrae and the intervening soft tissue elements.

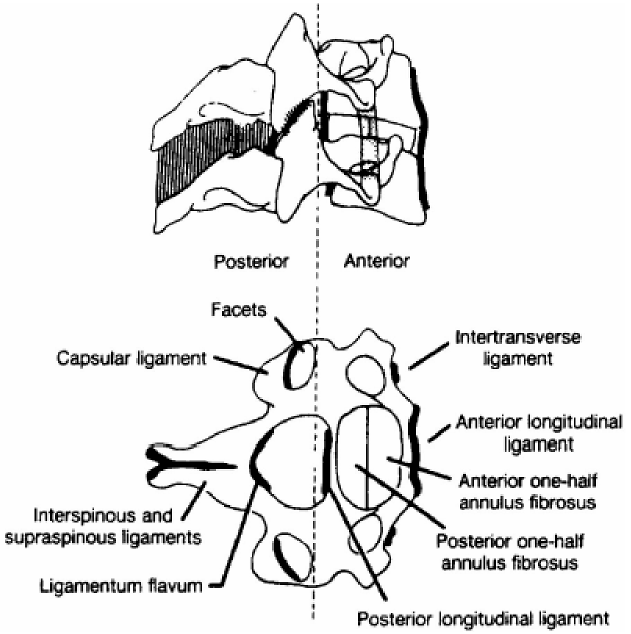


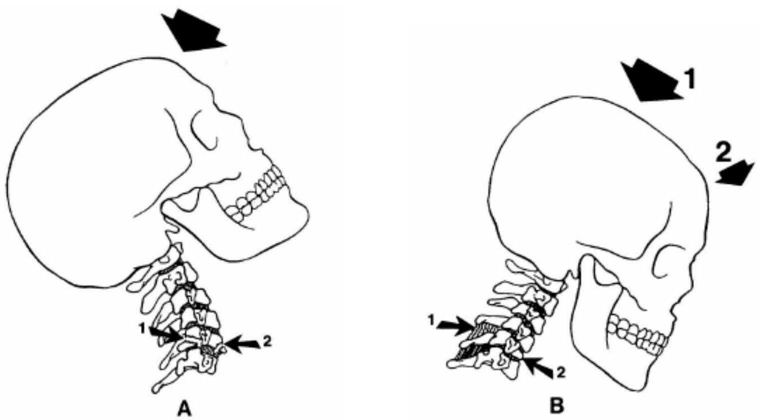
Fig. 3. Schematic representation of the two column concept of the spine. From White AA III, Panjabi MM: Clinical biomechanics of the spine. Philadelphia, JB Lippincott, 1978; used with permission.

Cervical Spinal Instability after Injury: Mechanisms and Consequences

Instability is that which occurs when physiologic loading causes patterns of vertebral displacement that jeopardize the spinal cord or nerve roots. Instability may be due to congenital anomalies, acquired conditions related to chronic disease, and acutely after trauma which is the focus of this discussion.

Ligamentous structures, intervertebral discs, and osseous articulations have been extensively studied, and their major role in determining clinical stability has been demonstrated. Although the muscles in the neck exert some stabilizing forces, the contribution that they make toward clinical stability has not been studied.

The anterior column contributes more to the stability of the spine in extension, and the posterior column exerts its major forces in flexion.
The anterior elements tend to be disrupted in hyperextension injuries, and the posterior elements tend to be disrupted in hyperflexion injuries. With extreme flexion or extension or if either a compressive or rotational force is added, both columns may be disrupted.



Mechanisms of injury

Flexion injuries
These cause compression of the anterior column and distraction of the posterior column:

1) *wedge fracture* of the vertebral body without ligamentous injuries. These injuries are stable and are rarely associated with neurologic injuries.

2) *facet joint dislocation* may occur with more severe trauma – unstable and are associated with a high incidence of cord damage.
With bilateral facet joint dislocation there is anterior displacement of at least 50% of the width of the vertebral body on lateral radiograph

3) *atlanto-axial dislocation/subluxation* – due to rupture of the transverse ligament. It may be associated with fractures of the atlas or odontoid peg and occurs most often in older children and adolescents. Patients complain of neck pain, occipital neuralgia, and occasionally symptoms of vertebrobasilar artery insufficiency (which may lead to infarcts)
The potential exists for continued displacement of atlas on axis with resultant pressure on the spinal cord.
ADI < 3.5 mm in flexion, implies that the transverse ligament is intact;
- ADI 3-5 mm, transverse ligament is insufficient;
(this is a type II injury);
- in children up to 4.5 mm may be normal;

ADI > 5 mm:
- indicates failure of the alar ligaments;
- consistent w/ type III rotatory subluxation

4) *odontoid fractures*
flexion loading is the cause in the majority of patients, and results in anterior displacement of the dens
type 1 - avulsion fracture of tip of the dens caused by an avulsion of alar ligament, rare
type 2 - junction of dens and body of axis, most common;
- occur thru base of odontoid process & may be caused by either hyper-flexion or hyperextension forces

type 3 - extend into the body of the axis, allows the Atlas and the occiput to move as a unit, hence it is mechanically unstable

Flexion–rotation injuries

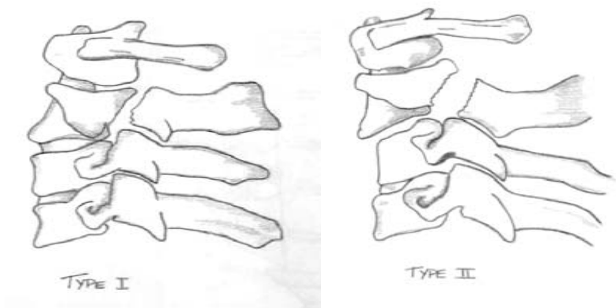
These commonly disrupt the posterior ligamentous complex and may also produce facet joint dislocation. They tend to be stable and are not usually associated with spinal cord injury, although cervical root injury is common.

Hyperextension injuries

These cause compression of the posterior column and distraction of the anterior column
Hyperextension combined with compressive forces may result in injury to the lateral vertebral masses, pedicles, and laminae. They are unstable and associated with a high incidence of cord injury.

1) *hangman's fracture.* (traumatic spondylolisthesis of the axis)
produced by violent hyperextension with fracture of the pedicles of the axis and forward movement of C2 on C3
Where there is neurologic injury, there will usually be significant horizontal translation with accompanying damage to the posterior longitudinal ligament with or without damage of the C2-C3 interspace.
judical lesion: hyperextension and distraction;
- hyperextension w/ vertical compression of posterior column, & translation of C2 and C3;
- forceful extension of already extended neck is most commonly described mech of injury, but other causes include:

-flexion of flexed neck & compression of an extended neck;
-a blow on the forehead forcing the neck into extension is a classic mechanism of injury producing fractures thru the pedicles of C2 known as traumatic spondyloslisthesis of C2



Hangman's fractures

Levine Classification

Type I: < 3 mm translation, no angulation, bilateral pars frx, prevertbral soft tissue swelling, normal disc space & normal alignment; C2-3 disk and ligamentous structures remain intact

type I A: extension of fracture through the foramen transversum (which may injure the vertebral artery

Type II: most common fracture subtype, greater than 3 mm translation, and greater than 10 deg angulation; unstable

Type III: includes all characteristics of type II as well as bilateral interfacetal dislocation

2) *atlanto-occiptal disassociation* (complete – dislocation or partial – subluxation)

The first report of traumatic AOD was attributed to Blackwood in 1908.14 This frequently fatal injury is caused by high-velocity accidents. Severe Hyperextension, rotation, and distraction are probably the most important mechanisms of injury. Severance of the tectorial membrane and the paired alar ligaments is a necessary accompaniment and requires extreme forces. Consequently the associated spinal cord damage is usually incompatible with life.

Children appear to be more susceptible to sustaining AOD than adults.16 The child's relatively larger head size, more horizontally oriented-AO joint, smaller occipital condyles, and weaker supporting ligaments all contribute to this increased vulnerability.

Neurological deficits in survivors are also attributed, at least in part, to the potentially reversible vascular consequences of the injuring forces. The carotid and vertebral arteries may be directly compressed by bony structures, or may be forcefully stretched, resulting in vasospasm or intimal tear with dissection or thrombosis.
Non traumatic atlanooccipital subluxation may occur, most frequently in Down's syndrome & rheumatoid arthritis

The clinical presentation may include:
No neurological deficit

- isolated cranial nerve deficits
- sensory deficits

- motor deficits – frequently asymmetrical, may be unilateral, quadriparesis or quadriplegia.

Hemiparesis is commonest

Deficits may improve after reestablishment of the cranio-vertebral alignment, presumably as a result of an improvement in the vascular supply.
Brain stem insults secondary to mechanical disruption, ischemia, or contusion may develop, leading to respiratory depression, arrest or agonal respirations, cardiac arrhythmias (bradycardia, asystole) , and decerebrate posturing.

Patients presenting with AOD have frequently also sustained a major head injury and it difficult to differentiate whether the neurologic findings are due to head injury or to local lower brain stem injury.

The classification system of AOD based on the direction of displacement of the occiput to the atlas was devised by Traynelis et al (Figure 4).

type I - the occiput moves anteriorly with respect to the atlas
type II - there is a longitudinal separation of the occiput and atlas
type III - the occiput has moved posteriorly with respect to the atlas rotatory dislocation is also possible.

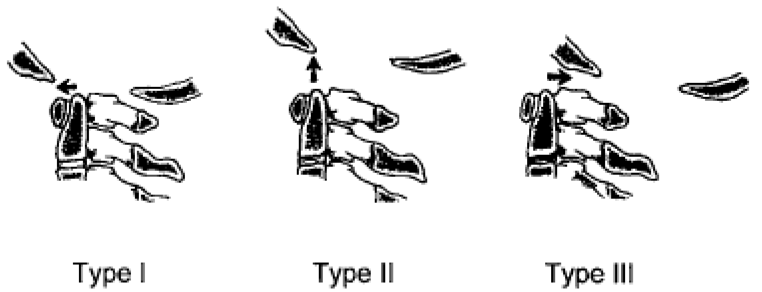


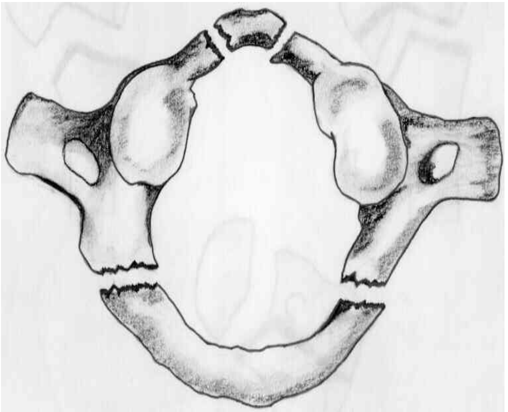
FIGURE 4 'Traynelis' classification of atlanto-occipital dislocations.

Often, the displacement is subtle, and retropharyngeal swelling due to haematoma accumulation may be the first insight into the diagnosis in an otherwise normal radiograph. The atlanto-Occipital Condyle Distance should be less than 5 mm regardless of age.

Axial loading

1) *burst fractures* - caused by compressive loading of the vertex of the skull in the neutral position. The pathology ranges from loss of vertebral body height with relatively intact margins, to complete disruption of the vertebral body. Although the spine is usually stable, posterior displacement (retropulsion) of comminuted fragments may produce cord injury.
2) *Atlas fractures* – involve the anterior arch, the posterior arch or both arches
3) *Jefferson fracture*: a 4 part burst fracture of the atlas, with combined anterior and posterior arch fractures. It is potentially unstable (if the transverse ligament is ruptured, ADI>4mm)

Approximately1/3 of these fractures are associated with an axis fracture and there is an approximately 50% chance that some other C-spine injury is present. Patients are usually neurologically intact - low rate of neurologic deficits is due to the large breadth of the C1 canal. However in cases of vertebral artery injury, neurologic injury can occur and may manifest as Wallenberg's syndrome with ipsilateral cranial nerve deficits, Horner's syndrome, ataxia, and loss of contralateral pain and temperature sensation.



Jefferson fracture

Distraction injuries

Pure distraction injuries are uncommon but if severe may result in ligamentous disruption leading to both instability and cord trauma

Determining Stability of the Cervical Spine after Injury

The following features found on lateral neck radiographs (or with flexion–extension views or dynamic fluoroscopy) are deemed abnormal and designated as instability:

1) Horizontal displacement exceeding 3.5 mm (corrected for x-ray magnification) or 20% of the vertebral body width
2) Angular displacement of a vertebral body >11° compared with an adjacent vertebra

The distance between the tip of the dens and the overlying basion in adults averages 5 mm; any distance greater than this is abnormal.

Not all cervical spine injuries result in clinical instability.
Two groups have categorized, by expert consensus, a number of injuries as not clinically important.

National Emergency X-Radiography Utilization Study (NEXUS) group

1) spinous process fractures
2) wedge compression fractures with loss of 25% or less of body height
3) isolated avulsion fractures without ligament injury
4) type 1 odontoid fractures
5) end-plate fractures
6) isolated osteophyte fractures
7) trabecular fractures
8) isolated transverse process fractures

Canadian CT Head and Cervical Spine Study group

1) Simple osteophyte fractures
2) transverse process fractures
3) spinous process fractures
4) compression fractures with loss of less than 25% of body height

Mechanisms of Spinal Cord Injury

These mechanisms and the various syndromes associated with cord injury will not be dwelled upon.
Primary injury-

1) Immediate neural damage may result from shear, compressive, ballistic, or distracting forces, which primarily avulse and devitalize tissues
2) Ischaemia – due to persistent cord compression from fracture–dislocation
3) laceration, contusion or concussion by bone fragment or missile

Secondary and progressive injury-

1) local perfusion deficits due to vascular compression by deranged anatomy (*e.g.*, tissue damage or edema)
2) global perfusion compromise caused by systemic hypotension
3) tissue hypoxemia as a result of hypoventilation caused by head or cord injury or by primary lung trauma.

Multiple mechanisms (too numerous and of little practical relevance) at a cellular and subcellular level may result in exacerbation of the injury resulting in an extension of the clinical deficit.

TABLE 2. *Spinal cord syndromes*

Syndrome	Setting	Clinical findings
Complete cord (cord transsection)	Trauma, infarction, hemorrhage, disc herniation, transverse myelitis, tumor, abscess	Loss of all motor and sensory function Cord transsection above C3 results in apnea and death unless prompt resuscitation
Brown-Sequard (cord hemisection)	Penetrating trauma, multiple sclerosis, tumor, abscess	Ipsilateral loss of proprioception and motor function Contralateral pain and temperature loss Suspended ipsilateral loss of all sensory modalities
Central cord	Neck hyperextension, syringomyelia, intramedullary tumor	Motor impairment greater in upper than lower extremity Suspended sensory loss in cervicothoracic dermatomes
Anterior cord	Hyperflexion, disc protrusion, anterior spinal artery occlusion	Pain and temperature loss with sparing of proprioception Variable motor impairment
Posterior cord	Syphilis, vitamin B12 deficiency, posterior spinal artery disease, trauma, multiple sclerosis	Diminished proprioception and fine touch
Conus medullaris	Tumor, trauma, disc herniation, inflammation, infection	Extension to lumbosacral roots may produce both upper and lower motor neuron signs Spastic paraparesis, sphincter dysfunction, lower sacral "saddle" sensory loss

*Not a myelopathy but a radiculopathy or neuropathy involving lumbosacral nerves.

SPINAL MOVEMENT DURING AIRWAY INTERVENTIONS

Static radiography and dynamic fluoroscopy have been used to assess this. Those spinal movements that fall within physiologic ranges have usually been considered to be non-threatening to the cord; whether they are and remain so in a spine with a canal lumen already compromised by an acute, a chronic, or an acute superimposed on chronic anatomical derangement is by no means certain.

The Effects of Airway Maneuvers on the Injured Neck

Aprahamian[9] studied the effect of airway manoeuvers on a human cadaver, unstable spine model. The anterior and most of the posterior column were surgically disrupted; the interspinous and supraspinous ligaments were spared. Lateral cervical spine radiographs were taken during both basic and advanced airway maneuvers.

Basic maneuvers included chin lift, jaw thrust, head tilt, and placement of both oral and esophageal airways.
Advanced maneuvers included placement of the following: an esophageal obturator airway; an orotracheal tube placed with both a straight and a curved laryngoscopic blade; and a nasotracheal tube, blindly placed.
The findings might seem surprising:

Chin lift and jaw thrust resulted in expansion of the disc space more than 5 mm at the site of injury. When blind nasotracheal intubation was facilitated by anterior pressure to stabilize the airway, 5 mm of posterior subluxation occurred at the site of injury. The other advanced airway maneuvers produced 3–4mm of disc space enlargement. The study was repeated after the application of both soft and semirigid cervical collars; collars did not effectively immobilize the neck for either basic or advanced airway manoeuvers.

Hauswald[10] also determined the impact of basic airway maneuvers on cervical spine movement. Eight human traumatic arrest victims were studied within 40 min of death. All subjects were ventilated by mask, and their tracheas were intubated orally with a direct laryngoscope, over a lighted oral stylet and using a flexible laryngoscope, and nasally. Cinefluoroscopic measurement of maximum cervical displacement during each procedure was made with the subjects supine and immobilized by a hard collar, backboard, and tape.

The mean maximum cervical spine displacement was found to be 2.93 mm for mask ventilation, 1.51 mm for oral intubation, 1.85 mm for guided oral intubation, and 1.20mm for nasal intubation. Once again the less invasive mask ventilation caused more cervical spine displacement than the other procedures studied.

Airway maneuvers will result in some degree of neck movement, both in general and specifically at the sites of injury. The amounts of movement are small, typically well within physiologic ranges, and their impact on secondary neurologic injury has not been defined. However it would seem that the maneuvers generally advocated and taught for airway management in a potentially injured cervical spine (ie: jaw thrust) actually have the greatest potential for aggravating cord injury. Despite this there seems to be a very low incidence of secondary injury in c spine injured patients associated with airway clinical interventions.

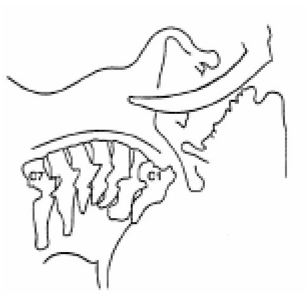


Fig. 6. Impact of direct laryngoscopy and tracheal intubation on cervical spine movement.[91,92]

Cervical Spinal Movement during Direct Laryngoscopy in Normal Patients

The following are the results of work by Sawin et al[11] on paralysed, anaesthetized normal human subjects
The most cervical motion occurs at the craniocervical junction (atlanto-occipital and atlantoaxial joints). Once inserted, elevation of the laryngoscope blade to achieve laryngeal visualization caused superior rotation of the occiput and CI (accentuated slightly by tracheal intubation) and mild inferior rotation of C3–C5. The subaxial cervical segments subjacent to and including C4 are minimally displaced (slight extension).

Another group led by Horton[12] had similar findings.

Seemingly then, only unstable injuries of C1 and 2 should cause anaesthesiologists concern before airway interventions.

Spinal Movement during Laryngoscopy in Injured Spine Models

Donaldson et al[14] looked at this in cadavers with intact and then unstable C1/2 segments:

With maximum flexion and extension, the SAC was narrowed 1.49 mm in the intact cervical spine but 6.06 mm in the unstable spine.
Chin lift and jaw thrust reduced the SAC by 1 mm and 2.5 mm, respectively oral intubation and nasal intubation created a similar (1.6 mm) reduction of SAC.
Distraction at the unstable injured level was similar for chin lift, jaw thrust, and crash intubation (1–2 mm); distraction during gentle oral intubation and nasal intubation was less than 1 mm.
Chin lift and jaw thrust created similar angulations (4°–5°) to those of the oral intubation techniques, but nasal intubation caused less (2.5°).
Cricoid pressure resulted in no significant movements when it was applied in either the stable or unstable model.
Donaldson *et al.* concluded that:

1) the SAC was narrowed to a greater degree by preintubation maneuvers than it was by intubation techniques
2) nasal and oral intubation techniques resulted in similar amounts of SAC narrowing, and
3) application of cricoid pressure produced no significant movement at the craniocervical junction.

Cervical Spinal Movement with Indirect Rigid Fiberoptic Laryngoscopes

Watts et al[13] compared cervical spine extension and time to intubation with the Bullard (ACMI Corp., Southborough, MA) and Macintosh laryngoscopes during a simulated emergency with cervical spine precautions taken.

Cervical spine extension (from the occiput to C5) was greatest with the Macintosh and was reduced both when the Macintosh was used with MILI and when the Bullard was used with or without stabilization. Times to intubation were similar for the Macintosh with MILI and for the Bullard without MILI.

MILI applied during laryngoscopy with the Bullard resulted in further reduction in cervical spine extension but a prolonged the time to intubation, although it still was achieved in less than a minute.

Bullard Laryngoscope
Bonfils laryngoscope

Similarly, spinal movement was much less with the Bonfils fibrescope as compared with the Macintosh laryngoscope as reported by Rudolph et al[15].

Cervical spine movements are generally less when rigid indirect laryngoscopes are used compared with the direct laryngoscope. Visualization of the glottis is also improved with the use of the rigid laryngoscopes, but the time to achieve the best view is somewhat longer; these times tend to be short, and the difference compared with the direct laryngoscope is likely to be of little clinical relevance.

Cervical Spinal Movement and Laryngeal Mask Airways

Limited work has revealed minimal flexion in the upper c spine (Kihara et al[16]) and high pressures which could produce displacement thereof (Keller et al[17]), but this remains speculation.

Cervical spinal movement and cricothyrotomy

Movements have been shown to be minimal but the clinical relevance thereof remains to be determined. (Gerling et al[18])

CERVICAL SPINE TRAUMA: EPIDEMIOLOGY AND CLINICAL CHARACTERISTICS

The incidence of CSI in victims of blunt trauma is estimated to be 0.9–3%,
In a US study:

- second cervical vertebra (C2) was the most common level of injury (24.0% of all fractures),
- 39.3% of fractures occurred in the two lowest cervical vertebrae (C6, C7)
- vertebral body was the most frequent anatomical site of fracture;
- nearly one third of all injuries (29.3%) were considered clinically insignificant

Also:-

- The majority of patients with CSI also have other injuries
- 25–50% of patients with CSI have an associated head injury
- the more severe the head injury (as determined by low GCS), the greater the likelihood of CSI
- focal neurologic deficit has been identified as a highly important clinical finding predicting spinal injury (hardly surprising)
- Patients with additional injuries are more likely to experience hypoxia and hypotension, both of which may not only prompt urgent airway intervention, but may also predispose to secondary neurologic injury.

Defining the Low-risk Trauma Patient

Why? to allow for selective use of diagnostic imaging in patients who have a low-risk of injury, thus reducing imaging use and patient exposure, conserving resources, and allowing for expedited and simplified care.

National Emergency X-Radiography Utilization Study

The NEXUS project attempted to derive a set of clinical criteria to identify blunt trauma victims at low risk for CSI.41 The decision instrument required patients to meet five criteria to be classified as having a low probability of injury:

(1) no midline cervical tenderness;
(2) no focal neurologic deficit;
(3) normal alertness;
(4) no intoxication; and
(5) no painful, distracting injury.

Distracting injuries were defined as including long bone fractures; visceral injuries requiring surgical consultation; large lacerations; burns; degloving or crush injuries; or any injury that might impair the patient's ability to participate in a general physical, mental, or neurologic examination.

The negative predictive value was 99.8%
The practice of withholding imaging for patients who meet these exclusionary criteria has been endorsed by recent neurosurgical guidelines.

The Canadian C-Spine Rule for Radiography after Trauma

The rule that was derived comprises three questions:

(1) Is there any high risk factor present that mandates radiography?
(2) Are there low-risk factors that would allow a safe assessment of a range of motion? and
(3) Is the patient able to actively rotate the neck 45° to the left and to the right?

C-Spine Rule was both more sensitive than the NEXUS criteria (99.4% *vs.* 90.7%) and more specific (45.1% *vs.* 36.8%) for injury.

The application of these protocols is complicated by the fact that there is a lack of agreement on the definitions of both *distracting injury* and *intoxication*. Failure to appreciate the degree of both distraction and intoxication may reduce the clinical index of suspicion for injury, resulting in missed diagnosis.

Radiographic Assessment after Blunt Trauma

A cross-table lateral radiograph, of acceptable quality and interpreted by an expert, will disclose the majority of injuries.

However:

1) up to 20% of patients with cervical injury will have a normal study.
2) Half of cross-table views are deemed inadequate to properly assess the entire cervical anatomy
3) injuries at both the craniocervical and the cervicothoracic junctions are often not well visualized in the cross-table view.

The sensitivity of three views (cervical series) approximates 90%; but 1% of clinically important injuries will be missed even with a technically adequate cervical series.

A three-view cervical series supplemented by CT through areas that are either difficult to visualize or suspicious on plain radiography will detect most spinal injuries. The negative predictive value of this combination of studies is reported to be 99–100%

In the obtunded patient with a normal cervical series and appropriate supplemental CT of the cervical spine, the incidence of significant spine injury is less than 1%. High-resolution CT scanning with sagittal reconstruction of the entire cervical spine rather than directed scanning of only at-risk areas may be even more effective in capturing virtually all injuries.
CT had negative predictive values of 98.9% for ligament injury and 100% predictive value for unstable cervical injury.

MRI is less sensitive than CT for injuries in the upper and posterior cervical spine.
MRI identified a small number of patients with ligament injuries not diagnosed with CT, but none of these were deemed to be unstable injuries.

Summary:

In a patient at high risk for cervical injury, who cannot be evaluated clinically, a three-view cervical series supplemented by high-resolution CT scanning with sagittal reconstruction will reduce the likelihood of an occult fracture to less than 1%. After a technically adequate imaging series has been reviewed and cleared by a radiologist, it is prudent to remove cervical immobilization. If there is evidence of a neurologic deficit referable to the cervical spine despite the finding of normal cervical radiography and CT imaging, MRI should be considered.

Spinal Ligament Injuries and Spinal Cord Injury without Radiographic Abnormality [SCIWORA]

This occurs most often in paediatric population where it accounts for up to 2/3 of severe cervical injuries in children < 8 years of age, but can also occur in adults (up to 15% with SCI). The inherent elasticity of the paediatric cervical spine can allow severe spinal cord injury to occur in absence of x-ray findings.

- Causes
  - transverse atlantal ligament injury
  - fracture through the cartilaginous end plates (which are not visualized by x-rays)
  - interspinous ligamentous injury: in above 2 situations, flexion & extension views taken with pt awake will demonstrate injury in adults: acute traumatic disc prolapsed
  - cervical spondylosis hyperextension injury to a spine where the vertebral canal diameter is already compromised by spondylosis; excessive anterior buckling of ligamentum flavum into canal already compromised by posterior vertebral body osteophytes probably is cause of central cord syndrome
  - motor loss in arms > than in legs, & variable sensory loss;

SCIWORA is a diagnosis of exclusion.
An MRI may reveal haemorrhage or oedema of the spinal cord or pseudosubluxation (anterior displacement of up to 4 mm)

Spinal ligament injuries are of particular concern because of the high incidence of resultant spinal instability and the potential for cord injury (and exacerbation thereof).
It has been suggested that patients with ligament injury of the cervical spine without fractures frequently require urgent intubation, and not uncommonly, clinical evaluation is either not possible or not complete at the time that

intervention is required; delay in the diagnosis of injury is common in these patients.

These are the patients who could potentially have their cord injury exacerbated by exuberant airway interventions by anaesthesiologists. This syndrome makes a strong case for treating patients as C-spine injured where clinical assessment of neurological injury is not possible even though radiographs have been “cleared”.

Secondary Neurologic Injury after Cervical Spine Injury

Secondary injury may be precipitated in CSI victims when management is suboptimal (particularly failure to immobilize) but there is also evidence that neurologic deterioration occurs after acute injury despite appropriate management.
The reported incidence thereof ranges from 2 to 10% and is usually attributed to vascular perturbations (arterial insufficiency or venous thrombosis), inflammation or spinal cord oedema with MRI studies providing some evidence for these assertions.

This progressive post-injury course in some patients may result in ascension of injury level. In some instances, it is associated with clinical interventions including immobilization, traction, surgery and intubation. In other instances, no clear factors are associated, and in particular, both extrinsic cord compression and vascular interruptions have been excluded.

This troubling syndrome occurs with sufficient regularity for it to have been given a name: Ascending myelopathy.
This diagnosis must be considered when a secondary injury has occurred. There is natural temptation to attribute the deterioration to temporally related clinical interventions but, in fact, these interventions are rarely associated with neurologic sequelae.

Progressive neurologic injury after CSI may be inevitable in some patients because of pathophysiologic processes initiated at the time of the application of the injuring forces and may occur despite the provision of appropriate management. In the light of these assertions can anaesthesiologists ever be blamed for neurologic deterioration post airway intervention in the acute setting?

CLINICAL CARE OF THE SPINE-INJURED PATIENT

Spinal Immobilization in Trauma Patients

The chief concern during the initial management of patients with potential CSI is that neurologic function may be further compromised by pathologic motion of the injured vertebrae. Hence the current consensus among experts remains that all patients with the potential for a CSI after trauma should be treated with spinal column immobilization until injury has been excluded or definitive management for CSI has been initiated.

Management of the potentially traumatized spine emphasizes three principles:

(1) restoration and maintenance of spinal alignment,
(2) protection of the cord with preservation of intact pathways, and
(3) establishment of spinal stability.

Failure to immobilize in the context of missed or delayed diagnosis is associated with an increased incidence of neurologic injury.

The exclusion of unstable CSI is a priority for obvious reasons but also because prolonged immobilization is painful, uncomfortable and not without complications:

1) Cutaneous ulcerations (pressure sores): these are common, and the incidence increases when immobilization is prolonged beyond 48–72 h
2) Airway management, central venous access and line care, provision of oral care, enteral nutrition, and physiotherapy regimes are all made more difficult.
3) There may be some restriction to respiratory function (impaired chest wall mobility) and increased aspiration risk
4) The need for multiple staff to allow for safe positioning and transfer of immobilized patients makes barrier nursing more difficult and may result in higher rates of cross-contamination and infection in high-dependency units.
5) cervical collars have been associated with increased intracranial pressure (ICP) in both injured and healthy patients (although more modest in the latter) presumably due to venous compression. This could be significant in those who already have increased ICP and poor intracranial compliance.

These complications are time dependent, hence the need for prompt assessment and discontinuation of immobilization if appropriate.

Techniques and Devices for Preadmission Spinal Immobilization

The position in which the injured spine should be placed and held immobile is the much vaunted, "neutral position" but this position is poorly defined.

Sandbags and tape combined with a rigid cervical collar is the most effective method to limit cervical spine motion and hence sandbag–tape–backboard–collar and variations thereof have become the most commonly used extrication and transport assembly in prehospital trauma care to provide spinal immobilization.

Manual In-line Immobilization

The goal of manual in-line immobilization (MILI) is to apply sufficient forces to the head and neck to limit (not prevent) the movement which might result during medical interventions, most notably, airway management.

The MILI applicator either

1) grasps the mastoid processes with his/her fingertips and cradles the occiput (head-of-bed assistant) or
2) cradles the mastoids and grasps the occiput (side-of-bed assistant).

When MILI is in place, the anterior portion of the cervical collar can be removed to allow for greater mouth opening, facilitating airway interventions. Reapplication of the mechanical immobilization should occur promptly when airway interventions are complete. During laryngoscopy, the assistant ideally applies forces that are equal in force and opposite in direction to those being generated by the laryngoscopist to keep the head and neck in the neutral position. Avoiding traction forces during the application of MILI may be particularly important when there is a serious ligamentous injury resulting in gross spinal instability.

Although MILI seems to have the least impact of all immobilization techniques on airway management, it may make direct laryngoscopy more difficult (increase grade); this may be countered with anterior laryngeal or cricoid pressure, shown by Donaldson et al to not produce significant movement in the injured upper cervical spine.

PRACTICE OPTIONS FOR AIRWAY MANAGEMENT AFTER CERVICAL SPINE INJURY

There is no evidence to favour any mode of intubation in CSI patients.

There are studies attempting to address this issue but are limited by both their small sample size and their retrospective nature. However, they do reveal that neurologic deterioration in CSI patients is uncommon after airway management, even in high-risk patients undergoing urgent tracheal intubation. They are not sufficient to rule out the potential that airway management provided in isolation or as part of a more complex clinical intervention, even provided with the utmost care, may rarely result in neurologic injury.

Early opinion on airway management in CSI regarded oral intubation as dangerous because it allegedly caused excessive spinal movement, and this movement could lead to secondary injury. Such secondary injury could theoretically be avoided by the careful performance of nasotracheal intubation or cricothyrotomy, long regarded as the techniques of choice.

Currently there is discordant opinion expressed in the literature regarding the optimal means of securing the airway in patients with CSI.

Some neuroanaesthesia experts have pushed for the exclusive use of the fiberoptic bronchoscope to facilitate tracheal intubation in spine-injured patients for the following reasons:

1) The head and neck may be left in a neutral position, and little spinal movement is required to achieve laryngeal visualization and tracheal intubation.
2) The patient's protective reflexes are largely left intact, and the potential for deleterious movements and positioning is perhaps reduced.
3) A neurologic assessment can be made after intubation to ensure that there has been no change in the patient's status, although the accuracy of this evaluation may be diminished by sedation.
4) The patient can be positioned awake to increase the likelihood that potentially injurious position are avoided.

Survey evidence also supports the conclusion that many anaesthesiologists are of the opinion that it is the preferred option, especially in elective scenarios. This preference persists even among physicians who acknowledge limited skills with the device. However, there have been relatively few reports recognized in the literature regarding the use of the bronchoscope in the emergency management of the airway after trauma and there are no data to suggest that better neurologic outcomes are achieved with its use. In fact, the application of a technique by practitioners not expert in its use may carry risk. Failed awake intubation has been identified as a cause of morbidity and mortality in the latest analysis of difficult airway claims by the American Society of Anesthesiologists' Closed Claims Project.

Use of direct laryngoscopy with MILS after induction is also deemed an acceptable practice especially in urgent/emergent situations.

The advantages thereof:

1) anaesthesiologists are very experienced in its use.
2) Direct laryngoscopy can also be performed more quickly than some, but not all, alternative techniques
3) it does not require time to obtain and set up specialized equipment.

However, it has the potential to cause greater spinal movement than indirect techniques. In addition, if laryngoscopy is performed after the induction of general anaesthesia, the potential for difficult ventilation, a failed intubation, and a cannot-intubate, cannot- ventilate scenario cannot be excluded.

Other practice options, such as light wands, rigid fibreoptic laryngoscopes, and laryngeal mask airways, are also deemed acceptable. There is no published evidence that would indicate that one intubation option is superior to others with respect to outcomes in general and, in particular, with respect to neurologic outcomes.

SUMMARY

CSI (particularly fractures) commonly affects the upper cervical spine (C1/2).

Anaesthesiologists cause more movement in the upper C spine then the lower C spine through airway interventions particularly basic airway manoeuvres and therefore could potentially exacerbate neurological injury in this area.

However this is offset by the smaller proportion of the canal occupied by the cord at this level providing an inherent safety margin, and hence neurologic injury is uncommon here.

Progressive neurological deterioration (ascending myelopathy) may occur despite appropriate management (ascension above C1/2 is hardly likely) and anaesthesiologists should not be blamed.

There is no published evidence that would indicate that one intubation option is superior to others with respect to outcomes in general and, in particular, with respect to neurologic outcomes.

Risk of cord injury during direct laryngoscopy with MILS is unknown but probably small (>300 published cases of DL with MILS in unstable spines without new neurologic deficit).

<u>A reasonable approach to manage the airway in a trauma patient with an unstable neck:</u>

Fibreoptic scope probably first choice if appropriate.

If not (blood in airway, combative patient) – consider Bullard, glidescope.

If above unsuitable (blood in airway, inexperience, dire emergency):
– perform direct laryngoscopy with MILS – The front half of the collar should be removed and the assistant should allow some "give" to enable glottic visualisation (true neutrality often not compatible with glottic exposure).

If DL not possible or ill advised: surgical airway.

If anaesthesia already induced – insert LMA while awaiting urgent tracheostomy/cricothyroidotomy (avoid multiple attempts at DL).

Avoid hypotension and avoid sux if SCI is >24hrs old.

REFERENCES

1. Crosby ET. Airway Management in Adults after Cervical Spine Trauma. Anesthesiology 2006; 104:1293–318
2. Crosby ET, Lui A. The Adult Cervical Spine: Implications for airway Management. CAN J ANAESTH 1990 / 37: 1 / pp77-93
3. Crosby ET. Airway Management after Upper Cervical Spine Injury: What have we learned? CAN J ANESTH 2002 / 49: 7 / pp 733–744
4. Ollerton JE, Parr MJR, Harrison K et al. Potential cervical spine injury and difficult airway management for emergency intubation of trauma adults in the emergency department—a systematic review. *Emerg. Med. J.* 2006;23;3-11
5. Ivy ME, Cohn SM. Addressing the Myths of Cervical Spine Injury Management. Amer Jour Emerg Med 15:6 Oct 1997.
6. Todd MM. Evaluation and Management of Cervical Spine injury. ASA Annual meeting refresher course lectures. Oct 2007
7. Wilson G. The Management of Acute Spinal Cord Injuries. FCA part 2 Refresher course lectures 2007
8. www.wheelessonline.com
9. Aprahamian C, Thompson BM, Finger WA, Darin JC: Experimental cervical spine injury model: Evaluation of airway management and splinting techniques. Ann Emerg Med 1984; 13:584–7
10. 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
11. Sawin PD, Todd MM, Traynelis VC, Farrell SB, Nader A, Sato Y, Clausen JD Goel VK: Cervical spine motion with direct laryngoscopy and orotracheal intubation: An *in vivo* cinefluoroscopic study of subjects without cervical abnormality.Anesthesiology 1996; 85:26–36
12. Horton WA, Fahy L, Charters P: Disposition of the cervical vertebrae, atlanto-axial joint, hyoid and mandible during x-ray laryngoscopy. Br J Anaesth 1989; 63:435–8
13. Watts ADJ, Gelb AW, Bach DB, Pelz DM: Comparison of Bullard and Macintosh laryngoscopes for endotracheal intubation of patients with a potential cervical spine injury. Anesthesiology 1997; 87:1335–42
14. Donaldson WF III, Heil BV, Donaldson VP, Silvagglo VJ: The effect of airway maneuvers on the unstable C1-C2 segment: A cadaver study. Spine 1997;22:1215–18
15. Rudolph C, Schneider JP, Wallenborn J, Schaffranietz L: Movement of the upper cervical spine during laryngoscopy: A comparison of the Bonfils intubation fiberscope and the Macintosh laryngoscope. Anaesthesia 2005; 60:668–72

16. Kihara S, Watanabe S, Brimacombe J, Taguchi N, Yaghuci Y, Yamaski Y: 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
17. 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
18. Gerling MC, Davis DP, Hamilton RS, Morris GF, Vilke GM, Garfin SR, Hayden SR: Effect of surgical cricothyrotomy on the unstable cervical spine in a cadaver model of intubation. J Emerg Med 2001; 20:1–5
19. Stevens RD, Bhardwaj A et al. Critical Care and Perioperative Management in Traumatic Spinal Cord Injury. *Journal of Neurosurgical Anesthesiology* Vol. 15, No. 3, pp. 215–229