Special Article

Neurological deterioration during intubation in cervical spine disorders

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ABSTRACT

Anaesthesiologists are often involved in the management of patients with cervical spine disorders. Airway management is often implicated in the deterioration of spinal cord function. Most evidence on neurological deterioration resulting from intubation is from case reports which suggest only association, but not causation. Most anaesthesiologists and surgeons probably believe that the risk of spinal cord injury (SCI) during intubation is largely due to mechanical compression produced by movement of the cervical spine. But it is questionable that the small and brief deformations produced during intubation can produce SCI. Difficult intubation, more frequently encountered in patients with cervical spine disorders, is likely to produce greater movement of spine. Several alternative intubation techniques are shown to improve ease and success, and reduce cervical spine movement but their role in limiting SCI is not studied. The current opinion is that most neurological injuries during anaesthesia are the result of prolonged deformation, impaired perfusion of the cord, or both. To prevent further neurological injury to the spinal cord and preserve spinal cord function, minimizing movement during intubation and positioning for surgery are essential. The features that diagnose laryngoscopy induced SCI are myelopathy present on recovery, short period of unconsciousness, autonomic disturbances following laryngoscopy, cranio-cervical junction disease or gross instability below C3. It is difficult to accept or refute the claim that neurological deterioration was induced by intubation. Hence, a record of adequate care at laryngoscopy and also perioperative period are important in the event of later medico-legal proceedings.

Key words: Cervical spine, instability, movement, neurological deterioration, stenosis, tracheal intubation

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INTRODUCTION

Anaesthesiologists are often involved in the management of patients with cervical spine disorders. The most crucial step in managing these patients is the prevention of further insult to the cervical spine (C-spine). Patients sometimes deteriorate neurologically during the perioperative period. Airway management is frequently implicated in the neurological deterioration. However, there have only been a few case reports of possible damage to the spinal cord from intubation.[1-9] There are no randomised studies involving intubation in actual spine pathology, and it is very hard to imagine an Ethical Committee approving such a trial. There are several reports of safety of laryngoscopy in patients with cervical spine injury as well.[10-19] Hence, it is difficult to implicate intubation as a sole contributor to spinal cord injury (SCI). The natural course of the pathology, surgical insult and the haemodynamic changes may also contribute to neurological deterioration. However, the emphasis is mostly on the cervical movements during intubation. Literature shows that intubation is easier and cervical movement is lesser with the alternative techniques to laryngoscopy for intubation. However, there is no clear evidence that cervical movements produced during intubation cause SCI or that the injury has been reduced by techniques that reduce

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cervical movement during intubation. This should not underscore the need to exert caution while intubating patients with cervical spine disorders. The knowledge of individual factors potentially contributing to injury and population at risk for new onset cervical injury is important for anaesthesia providers to manage the patients with cervical spine disorders and also lessen the culpability and legal risk.

This review focuses on what currently exists in the literature regarding neurological deterioration following intubation and address certain dogmas that surround intubation and cervical spine.

DEFINITION OF CERVICAL INSTABILITY

Cervical instability is defined as loss of the ability under normal physiologic loads to maintain relationships between vertebrae in such a way that there is either initial or subsequent damage to the spinal cord or nerve roots, and there is development of incapacitating deformity or severe pain[20] [Table 1]. Clinical cervical spine instability is often difficult to diagnose and may involve subtle clinical features. Many times intubation may be required even before the spine is cleared for instability. It must also be emphasised that spinal stability does not confer immunity from risk of injury. Intraoperative SCI and neurological deterioration can occur even in the absence of cervical instability.[21-25]

Table 1: Definition of instability

Symptomatic
Loss of the ability under normal physiologic loads to maintain relationships between vertebrae in such a way that there is neither initial nor subsequent damage to the spinal cord or nerve roots, and there is neither development of incapacitating deformity or severe pain
Radiological measurements
White and Panjabi criteria for instability of the C0-C1-C2 complex
Axial rotation C0-C1 to one side >8^0
C0-C1 translation >1^0,
Overhang C1-C2 (total right and left) >7mm
Axial rotation C1-C2 to one side >45^0
C1-C2 translation >4mm
Posterior body C2-posterior ring C1 <13 mm
Avulsed transverse ligament
White and Panjabi criteria for instability of mid and lower cervical spine
Anterior element destroyed or unable to function-2
Posterior element destroyed or unable to function-2
Positive stretch test-1
Resting/flexion extension saggital plane translation >3.5 mm or 20% -2
Resting saggital angulation >11^0 or >20^0 on flexion extension >20^0-2
Narrow spinal canal (<13 mm Saggital diameter or Pavlov's ratio <0.8) -1
(Ratio of AP diameter of canal to AP diameter of vertebral body)
Abnormal disc narrowing-1
Spinal cord damage-2
Nerve root damage-1
The diagnosis of clinical instability of the cervical spine can be made when the total score is 5 or more
These values have been widely used, but there is a poor correlation between radiographic abnormality and neurological symptoms and signs

EVIDENCE OF CERVICAL INJURY FOLLOWING INTUBATION

Most evidence on neurological deterioration resulting from intubation is from case reports as double-blinded trial is ethically not feasible in this area of anaesthetic practice. The actual number of published reports is small. The reasons may be either due to the low incidence of perioperative cervical cord injury or these incidents may not be reported due to potential or actual medical mal-practice liability. The published reports are summarised in Table 2. Most of the reports describe only a temporal association between a devastating deterioration in neurological function and the airway management but not causation.

Approximately, 5% of patients admitted with traumatic cervical injury will deteriorate neurologically.[26] It is possible that the episode of neurological deterioration might coincide with an anaesthetic. In most reports there was a pre-existing unrecognised damage to the spinal cord that may have worsened during the procedure to create an impression that airway management resulted in injury.[1,5,8] It is also possible that when there is no suspicion of cervical spine abnormality protective measures would not have been undertaken. There are reports of SCI even without intubation.[27] There are reports of cord injury in normal subjects after prolonged[25] or even short periods of extreme spinal deformation.[28] However, it is hard to point to any convincing report of an actual case of neurological deterioration due to intubation.

The general anaesthesia claims in the closed claims database between 1970 and 2007 was reviewed by Hindman *et al*.[29] The closed claims database contains even the unreported events. The airway management was implicated in only 11% of the claims. Probable contributors to cord injury included anatomic abnormalities (81%), direct surgical complications (24%) (38% were cervical spine procedures), pre-procedural symptomatic cord injury (19%),

Table 2: Summary of published reports of new neurological deficit following intubation

References	n	Underlying pathology	Intubation	Time of deterioration	Comments
Powell *et al.*[1]	1	AAD (down's)	Laryngoscopy	Post-intubation	Unrecognized at intubation
Yaszemski and Shepler[2]	1	AAD (Rhuematoid)	Emergency intubation during CPR	Post-mortem cord changes	No precautions for immobilization
Hastings and Kelley[3]	1	Spinal canal stenosis	Failed intubation	Seen after intubation for CPR	Hypoxia and hypotension also present
Powell and Heath[4]	1	Unrecognized peg fracture	Laryngoscopy	Post-intubation	Intubation without immobilization
Yan and Diggan[6]	1	None	Laryngoscopy	1-day postoperative	Cord contusion on MRI
Muckart *et al.*[5]	2	Trauma	Laryngoscopy	Post-intubation	Unrecognized preoperative
Farmer *et al.*[7]	4	Trauma	Laryngoscopy	Post-intubation	Information inadequate
Redl[8]	1	Congenital cranioverbral	Laryngoscopy	Post-intubation	Unrecognised preoperative
Edge *et al.*[9]	1	Unrecognised cervical pathology	LMA	Post-procedure	Rupture of the posterior spinal ligament with haematoma cord compression

AAD – Atlanto-axial dislocation; CPR – Cardiopulmonary resuscitation; LMA – Laryngeal mask airway; MRI – Magnetic resonance imaging

intraoperative head/neck position (19%), and airway management (11%).[29] The causes of canal stenosis should generate equal concern in addition to instability.

POSSIBLE MECHANISM OF SPINAL INJURY DURING INTUBATION

It is important to understand about experimental and clinical evidence about the induction of acute myelopathy during intubation. Although unproven, the current opinion is that most neurological injuries during anaesthesia are the result of prolonged deformation, impaired perfusion of the cord, or both.

Cervical movements during intubation

There are frequent publications that describe the extent to which various routinely used airway management techniques angulate the C spine.[30-44] The available evidence suggests that, in unstable cervical spines, basic airway manoeuvres such as chin lift and jaw protrusion cause as much displacement as direct laryngoscopy.[44-46] However, the necessity of basic airway management cannot be avoided whenever a patient is anaesthetised. It can be argued that airway devices should be placed in the awake patient. However, there is no evidence that using an awake procedure results in better neurological outcome. The analysis of the American Society of Anaesthesiologists closed claims contained several examples of serious morbidity and mortality caused by awake fibreoptic intubation.[47]

The majority of cervical spinal movement occurring during direct laryngoscopy is concentrated in the upper cervical spine. There is minimal movement below C3.[48,49] Since the movement during laryngoscopy is concentrated in the occipito-atlanto-axial (OAA) complex,[45] diseases at this level are at greater risk of SCI. The movement of unstable spine might be different, but it is difficult to study the unstable spine. Most data regarding cervical movement is from trials of uninjured patients or cadaveric models of destabilised cervical spine.[45,32,50,34] The magnitude of movement during airway management rarely exceeds the physiological limits of the spine. Lennarson *et al.* studied movements at C5-C6 before and after surgical destabilisation of cadavers.[34] They found a difference of <2 mm translation and 4° angulation between the stable and unstable spine. It is therefore questionable that these small deformations produced for a brief few seconds can produce SCI. Movement is reduced by in-line immobilisation,[51] but traction forces cause clinically important distraction[52] and should be avoided.

Contribution of vascular compromise to spinal cord injury

The contribution of vascular compromise to SCI during anaesthesia is most often under-emphasized while the consequences of movement over-emphasised. The duration of compression is an important factor unless the deformation is extreme. It is believed that prolonged compression and/or stretching of nervous tissue even to a minor degree eventually result in hypoperfusion of the cord.[53] The compression of the cord during laryngoscopy has not been quantified. Flexion of the spine causes elongation of the cord with narrowing of the diameter of longitudinal vessels and extension causes increase in the cord diameter and folding of ligamentum flavum, which exerts pressure on the cord and posterior longitudinal vessels. Flow through radicular vessels is believed to be obstructed during cervical movement. Alteration of spinal curvature can increase cerebrospinal fluid pressure and reduce cord perfusion pressure by 20 mm Hg.[54] However, limited available evidence suggests that allowing some flexion or extension of the head is unlikely to cause secondary injury and may facilitate prompt intubation in difficult cases. Patients with pre-existing myelopathy are probably at greater risk.

SAFETY OF LARYNGOSCOPY IN UNSTABLE CERVICAL SPINE

The potential merits and dangers of laryngoscopy for intubation in patients with injury to the cervical spine or spinal cord continue to be debated. The reports of safe use of direct laryngoscopy are given in Table 3.

It is important to note that the intubations were performed by experienced personnel in all these reports with maintenance of stabilisation. They reported no statistically significant difference in neurological deterioration between intubated and un-intubated patients with critical cervical spine injury.[19] There were no differences in neurological outcome whether intubation was performed while the patient was awake or under general anaesthesia, or comparing oral tracheal intubation with other techniques.[10,17,19] Shatney *et al*. have reported safety of orotracheal intubation in patients with unstable high cervical fractures.[16] It is expected that undiagnosed cervical spine injury requiring immediate airway control would have a worse neurological outcome. However, no worsening of neurological outcomes occurred in patients managed with emergency orotracheal intubation in hitherto unrecognised cervical spine injury.[18] While it will never be possible to prove that direct laryngoscopy is completely safe, it is accepted that establishing a tracheal airway takes precedence over theoretical risks in practice.

NEED FOR ALTERNATIVE AIRWAY MANAGEMENT IN CERVICAL SPINE DISORDERS

Cervical spine disorders can be associated with difficult intubation. Pre-anaesthetic prediction of difficult laryngoscopy remains problematic.[55] A poor glottic view could pose a hazard to patients with unstable cervical spines if/when the laryngoscopist applies additional force in attempts to improve glottic visualisation.

Table 3: Safety of laryngoscopy in cervical spine trauma

Population and references	Techniques	New neurologic deficit
n=150; Suderman *et al*., 1991[10]	All needed intubation for surgical stabilization GA and DL, 67 GA, other technique, 14 (FOB, lighted stylet, blind nasal) Awake FOB, 37 Awake DL, 22 Awake lighted stylet, 8	2 patients (1.3%) 1 radiculopathy, resolved after 72 h 1 quadraplegia, surgical wire passed through cord
n=60; Wright *et al*., 1992[12]	53 had unstable injuries Oral intubation, 26: Nasal intubation, 25: Cricothyrotomy, 2	1 patient (1.8%) after nasal intubation
n=454; Meschino *et al*., 1992[11]	165 (36%) patients needed intubation Awake FOB, 76: Awake blind nasal, 53: Awake DL, 36	11 patients total (2.4%) 7 nonintubated, 4 intubated 2 before intubation, 2 several hours after normal postintubation exam
n=168; Scannell *et al*., 1993[13]	81 needed intubation, all with RSI	None; 4 had improvement in deficit after intubation
n=393; Criswell, 1994[14]	104 needed intubation RSI, 73; blind nasal, 18 FOB, 11; cricothyrotomy for failed intubation, 2	No new deficit (95% confidence interval 0-4%)
n=102: Lord *et al*., 1994[15]	62 required intubation Airway control methods nasotracheal: 14 (22%): orotracheal: 27 (43%), FOB: 17 (27%) Tracheostomy: 1 (2%), unknown: 3 (4%)	No progression of the neurological status
Shatney *et al*., 1995[16]	Unstable fractures and also high cervical fractures	No further neurologic deficit
n=45 McCrory *et al*., 1997[17]	16 patients-preoperative neurological deficit Awake FOB-27 GA-17 (I.V), 1 (inhalational)	No new neurological sequelae
n=37 Patterson, 2004[18]	Emergency orotracheal intubation in unrecognised CSI were subsequently verified to have a CSI	No worsening of neurological outcomes
n=68, Kawamoto *et al*., 2010[19]	DL (group L; 36 patients) or FOB (group F; 32 patients)	No significant differences in postoperative neurologic outcome

GA – General anaesthesia; DL – Direct laryngoscopy; FOB – Flexible fibreoptic bronchoscope; RSI – Rapid-sequence intubation; CSI – Cervical spine injury

Causes for difficult airway management in cervical spine disorders

There may be greater difficulty in obtaining a good laryngeal exposure when manual in-line stabilization (MILS) is applied.[56] Ethical and methodologic constraints preclude controlled trials of MILS though recent work questions its effectiveness. Cervical spine disease is in itself a cause of difficult direct laryngoscopy. Lesions affecting the OAA complex are the most likely to result in difficult laryngoscopy.[57] Iatrogenic causes (fixators, collars) and arthritic processes are additional contributing factors.[58] Reduced mouth opening often compounds the problem of poor OAA extension. Arthritic involvement of the temporo-mandibular joint (TMJ) may be present, but OAA extension is necessary for normal mouth opening even in subjects with normal TMJ.[55]

Alternatives to direct laryngoscopy

Despite the presumed safety and efficacy of direct laryngoscopy with MILS, persevering with difficult direct laryngoscopy may be unsafe in many patients, particularly 'unstable' patients who are functionally preserved. Alternative techniques that do not require direct visualisation warrant investigation. Safety of awake fibreoptic intubation in patients with cervical spine disorders is established. Promising alternative techniques include intubation through supraglottic airways, lightwand, optical stylets, Bullard laryngoscope, intubating laryngeal mask airway, with/without fibreoptic guidance, C-Traq, video laryngoscopes such as Glidescope Airway Scope, Airtraq. The cervical movement with the alternative techniques of intubation are summarised in Table 4. The indirect techniques for tracheal intubation cause less cervical movement than does the direct laryngoscope. Fibreoptic stylets and periscope-like devices allow trained clinicians to apply MILS and obtain better visualization, possibly with less force. However, there is lack of evidence that one method of airway management in patients with cervical disease is better than another in terms of efficacy, safety and neurological outcome. Practitioners should use a technique in which they are competent.

PREVENTION OF NEUROLOGICAL DETERIORATION

McLeod and Calder[71] identified features that diagnose laryngoscopy induced SCI as myelopathy present on recovery, short period of unconsciousness, autonomic disturbances following laryngoscopy, cranio-cervical junction disease or gross instability below C3. The problem with anaesthesia is that it results in loss of consciousness and the ability to detect the consequences. It is therefore prudent to focus on prevention of neurological injury.

Reduction of movement

Intubation

We should attempt to minimise movement of the head and neck during airway management, as studies in cadavers and anaesthetised patients have shown that some movement of the cervical spine occurs during all airway manoeuvres including insertion of an airway.

Position

Prolonged minor malposition may be the cause of some cord injuries so, as far as requirements for surgery render possible, the position should look comfortable. Any position that looks uncomfortable must be avoided.

Maintaining spinal cord perfusion

Spinal cord injury leads to profound haemodynamic changes due to vascular, cardiac and autonomic dysfunction.[72] It causes reduction in spinal cord blood flow autoregulation and carbon dioxide reactivity, which are closely related to the severity of injury.[73] Manipulating physiological parameters such as mean arterial blood pressure (MABP) and intrathecal pressure may be beneficial for patients with an SCI.

Maintenance of normotension

Most patients will have some degree of cord or root compression, and it is important to maintain a good perfusion pressure. Maintaining normotension under anaesthesia is usually difficult and might involve inotrope infusions. Hypertension may, in theory at least, promote cord swelling in damaged areas.[74] Surgical bleeding may also demand a lower than normal pressure. In practice, a systolic pressure of >100 mm Hg and MABP of 80–85 mm Hg is the aim in normotensive patients.[72] The blood supply to the spinal cord is believed to be similar to the cerebral circulation in terms of regulation of flow. Though it has been suggested that a watershed (area of relatively reduced reliability of perfusion) exists at the cervico-thoracic junction recent report suggests that the cord is most likely to suffer ischaemic events at the C2-C3 level.[75]

Table 4: Comparison of cervical movement of airway management techniques

Technique of intubation	Comparison	Observation
Laryngoscope blades	Miller straight blade, Macintosh curved blade and Corazelli-London-McCoy hinged blade	Miller blade <Mc Coy <macintosh[50] McCoy <Miller <Macintosh[59]
Airway manoeuvres	FOB	Pre-intubation maneuvers >FOB[44]
Supraglottic devices	Macintosh blade, McCoy Blade, LMA, I-LMA, and Combitube	Movement with Supraglottic devices equal to DL[60]
Intubating laryngeal mask airway	Baseline	ILMA produces segmental movement of the cervical spine, despite MILS. Movement is opposite to DL[33]
	Macintosh laryngoscope, FOB oral and nasal intubation	FOB nasal <FOB oral <ILMA <Macintosh[61]
	Macintosh laryngoscope, FOB	FOB oral <ILMA <Macintosh[35]
Belscope	Macintosh laryngoscope	No difference[31]
Augustine guide	Macintosh laryngoscope	Augustine guide <Macintosh[30]
Bonfils intubation	Macintosh laryngoscope	Bonfils fibrescope <Macintosh blade[62]
Bullard	Macintosh, Bullard with and without MILS	Bullard laryngoscope with MILS <without MILS <Macintosh blade[63]
Truview laryngoscope	Macintosh laryngoscope	Truview <Macintosh blade[64]
Flexiblade	Macintosh laryngoscope	Flexiblade <Macintosh blade[65]
Airtraq laryngoscope	Macintosh laryngoscope	AirTraq laryngoscope <Macintosh[43,39]
Glidescope (R)	Macintosh laryngoscope	Glidescope <DL[66]
	Macintosh laryngoscope	No difference[41]
	FOB	Glide scope >FOB[44]
Airwayscope (pentax-AWS)	Baseline	Produces the anterior movement[67]
	With and without a bougie	Use of the bougie significantly reduced extension[68]
	Macintosh or McCoy laryngoscope	AWS <Macintosh or McCoy laryngoscope[40]
	Macintosh laryngoscope	AWS <Macintosh blade[38,69]
Trachlight (R)	Flexible fiberoptic bronchoscope	TL=FOB[42]
Shikani optical stylet	Macintosh laryngoscope	SOS <Macintosh blade[70]
Lightwand	Macintosh laryngoscope, Glidescope	Lightwand <Glidescope and Macintosh blade[37]
Multiple techniques	Macintosh, Bullard laryngoscope, a Bonfils fibrescope and intubating laryngeal mask	Bullard laryngoscope may be a useful adjunct. Bonfils and intubating laryngeal mask useful alternatives[36]
	Macintosh laryngoscope, (FOB-nasal), ILMA with FOB, LMA, esophageal tracheal combitube	FOB (nasal) <ILMA + FOB <combitube <laryngoscope[32]

ILMA – Intubating laryngeal mask airway; SOS – Shikani optical stylet; FOB – Flexible fibreoptic bronchoscope; LMA – Laryngeal mask airway; MILS – Manual in-line stabilization; DL – Direct laryngoscopy; Airway scope; TL – Traditional laryngoscopy

TREATMENT OF SPINAL CORD INJURY RECOGNIZED POST-OPERATIVELY

There are no firm guidelines available, hence only treatment options are listed based on several steps that can be taken to help minimize damage from the secondary cascade following recognition of an intraoperative SCI or postoperatively recognised SCI.

Early recognition is important to reduce the impact of the injury as soon as possible. MABP should be maintained above 80–85 mm Hg and the haematocrit should be corrected. Treatment with methyl prednisolone sodium succinate (MPSS) can also be initiated as soon as possible after identification of the SCI though there is no firm evidence for its use in this setting. Based on the recommendations of Bracken[76] a 30 mg/kg bolus of MPSS is given over 15 min and after 45-min, an infusion of 5.4 mg/kg/h is given. MPSS is continued for a total of 24 h.

LEGAL IMPLICATIONS

There is widely prevailing dogma that direct laryngoscopy is hazardous in the presence of cervical instability. It would be sad if any case of tracheal intubation in a patient with an unstable neck was brought to the courts based on this unsound dogma. It is difficult to prove and even harder to disprove laryngoscopy as a cause for SCI. Pre-operative neurological findings and any precautions taken should be recorded. A record of adequate care at laryngoscopy and also during the whole of anaesthesia and postoperative period are important in the event of later medico-legal proceedings.

CONCLUSION

The debate on implication of airway management for the neurological deterioration though cervical SCI produced by airway manoeuvres continues. The current evidence is insufficient to conclude on safety or lack of thereof, for airway management in the presence of cervical spine instability. There have only been a few case reports of possible damage to the spinal cord from airway management. As long as we take careful measures to protect the neck (such as manual in-line head and neck stabilisation), direct laryngoscopy and tracheal intubation can be performed safely without damaging the cervical spine in the majority of patients. The current opinion is that most neurological injuries during anaesthesia are the result of deformation of cord, impaired perfusion, or both. Meticulous attention should also be paid towards maintenance of cord perfusion. Data demonstrating the safety of orotracheal intubation with MILS has caused the emphasis to shift from use of a specific technique to operator skill and comfort.

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