

Review Article

Airway management in patients with suspected or confirmed traumatic spinal cord injury: a narrative review of current evidence

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Summary

Around 1 million people sustain a spinal cord injury each year, which can have significant psychosocial, physical and socio-economic consequences for patients, their families and society. The aim of this review is to provide clinicians with a summary of recent studies of direct relevance to the airway management of patients with confirmed or suspected traumatic spinal cord injury to promote best clinical practice. All airway interventions are associated with some degree of movement of the cervical spine; in general, these are very small and whether these are clinically significant in terms of impingement of the spinal cord is unclear. Manual in-line stabilisation does not effectively immobilise the cervical spine and increases the likelihood of difficult and failed tracheal intubation. There is no clear evidence of benefit of awake tracheal intubation techniques in terms of prevention of secondary spinal cord injury. Videolaryngoscopy appears to cause a similar degree of cervical spine displacement as flexible bronchoscope-guided tracheal intubation and is an appropriate alternative approach. Direct laryngoscopy does cause a slightly greater degree of cervical spinal movement during tracheal intubation than videolaryngoscopy, but this does not appear to increase the risk of spinal cord compression. The risk of spinal cord injury during tracheal intubation appears to be minimal even in the presence of gross cervical spine instability. Depending on the clinical situation, practitioners should choose the tracheal intubation technique with which they are most proficient and that is most likely to minimise cervical spine movement.

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Introduction

Around 1 million people sustain spinal cord injury each year, which can have significant psychosocial, physical and socio-economic consequences for patients, their families and society in general [1]. The sequelae of spinal cord injury are often long lasting; in 2016, over 27 million people were living with spinal cord injury, resulting in 9.5 million years of

life lived with disability [1]. Falls and road traffic collisions are the most common cause, and the incidence is greater in regions with a high socio-demographic index such as North America and Western Europe (26 per 100,000 population) [1]. Data from the UK Trauma and Audit Research Network in 2018 showed that 9% of patients admitted to hospital following significant trauma had suffered a major spinal

injury [2]. The incidence of cervical spinal injury is lower; within a cohort of over 250,000 patients managed from 1988 to 2009, 2.5% of patients had a cervical fracture/dislocation, but only 0.8% suffered injury to their cervical spinal cord [3]. Although the incidence of spinal cord injury is relatively static, there has been an increase in central cord syndrome; this is due to global population ageing and the occurrence of spinal injury in people with an already narrowed spinal canal secondary to spondylosis and/or cervical stenosis [4].

Patients who have suffered injuries secondary to trauma often require their tracheas to be intubated; this may be as part of their initial resuscitation in the emergency department or to facilitate operative management of their injuries during their hospital admission. As approximately 40% of cervical spine injuries are judged to be unstable [5], clinicians are often concerned that tracheal intubation may worsen an existing neurological deficit or cause a new spinal cord injury. In addition, there is also the potential for other associated interventions, such as the application of cricoid force or face-mask ventilation, to influence cervical spine alignment. The optimal technique for tracheal intubation that will minimise any associated cervical spine movement remains controversial; historically, awake tracheal intubation using a flexible bronchoscope was the preferred technique, but the advent and ubiquitous availability of videolaryngoscopy has seen this approach become more common [6] and its use is now encouraged in national guidelines [7].

The aim of this review was to provide clinicians with a summary of recent studies that have investigated airway management techniques in patients with suspected or confirmed traumatic spinal cord injury.

Searches were performed in MEDLINE, PubMed, Web of Science, EMBASE, Cochrane Reviews, Cochrane Trails and Google Scholar for relevant studies relating to tracheal intubation in people with suspected or confirmed traumatic cervical spinal cord injury. The search strategy used is available in online Supporting Information (Appendix S1). The search included randomised controlled trials, clinical trials, systematic reviews and meta-analyses involving adults (age > 18 y) and was limited to studies published in English between 1 January 2018 and 1 June 2022. Key landmark studies published before this time, which have not been repeated or updated, were also included. The studies chosen for inclusion in this narrative review are those that, in the opinion of the author, have the greatest relevance to contemporary clinical practice. The studies selected were divided into distinct areas of airway management.

Results

Airway manoeuvres

No recent studies have investigated the impact of airway manoeuvres such as chin-tilt, jaw-thrust or face-mask ventilation. Jaw-thrust has been shown to produce less cervical spinal segment angulation than chin-tilt in a cadaveric study [8], although this is still greater than that observed during tracheal intubation using direct laryngoscopy [9]. This finding was confirmed in a cadaveric study with a surgically created C5/6 injury that showed that chin-tilt and jaw-thrust both reduced the space available for cord (SAC) to a greater degree than tracheal intubation using a Macintosh laryngoscope [10]. However, the change in SAC was very small and whether this is of clinical significance remains uncertain. The effect of face-mask ventilation was investigated in a study using cadavers without cervical spinal injury. The cervical spines of the cadavers were triple immobilised (hard cervical collar, backboard and tape) during the interventions. Face-mask ventilation caused a mean (SD) maximal cervical anterior–posterior displacement of 3.13 (1.59) mm which was significantly greater than that seen with tracheal intubation using a Macintosh blade (1.33 (0.57) mm) [11]. This study did not measure SAC, and thus the significance of this displacement in terms of the risk of spinal cord compression is unknown.

Manual in-line stabilisation

Manual in-line stabilisation (MILS) was popularised in the 1980s as part of Advanced Trauma Life Support guidelines. Although introduced on the basis of the precautionary principle, MILS continues to be used commonly during tracheal intubation, in an attempt to stabilise the cervical spine and minimise the risk of secondary cord injury. The efficacy of MILS in protecting the cervical spinal cord had been discussed in a recent review [12], with little evidence found that MILS reduces cervical segment movement; MILS may in fact increase subluxation of damaged segments [13]. In addition, MILS has several potentially deleterious effects that are of direct relevance to tracheal intubation.

The most important is a worsening of the laryngeal view during direct laryngoscopy, thereby increasing the risk of failed tracheal intubation. The application of MILS increases the incidence of a grade 3/4 Cormack–Lehane glottic view from < 5% to 22–58% [14–16] (Table 1). The use of alternative devices (including videolaryngoscopy) for tracheal intubation with cervical immobilisation in place was investigated in meta-analysis of 80 studies (n = 8039) [17]. Manual in-line stabilisation was used to immobilise the cervical spine in 48 studies and a cervical collar was used in

Table 1 The effect of cervical spine stabilisation on Cormack–Lehane grade of glottic view during direct laryngoscopy. Values are number (proportion).

		Grade 1	Grade 2	Grade 3	Grade 4
Heath [14]	Optimal position	46 (92%)	4 (8%)	-	-
	MILS	12 (24%)	27 (54%)	11 (22%)	-
	Collar/sandbags/tape	2 (4%)	16 (32%)	25 (50%)	7 (14%)
Nolan and Wilson [15]	Optimal position	129 (82%)	26 (17%)	2 (1%)	-
	MILS	75 (48%)	48 (31%)	34 (22%)	-
Thiboutot et al. [16]	Optimal position	77 (73%)	23 (22%)	5 (5%)	-
	MILS	7 (7%)	32 (34%)	44 (47%)	11 (12%)

MILS, manual in-line stabilisation.

30 studies. The McGrath laryngoscope (Medtronic Limited, Watford, UK) (OR 11.5 (95% credible interval (CrI) 3.19–46.20)), C-MAC D Blade (Karl Storz SE & Co. KG, Tuttlingen, Germany) (OR 7.44 (95%CrI 1.06–52.50)), Airtraq (Prodol Meditec S.A., Vizcaya, Spain) (OR 5.43 (95%CrI 2.15–14.2)), King Vision (Ambu, Ballerup, Denmark) (OR 4.54 (95%CrI 1.28–16.30)) and C-MAC (Karl Storz SE & Co. KG) (OR 4.20 (95%CrI 1.28–15.10)), all had a greater probability of first-pass tracheal intubation success compared with the Macintosh laryngoscope. However, when studies that used MILS were analysed separately, only the Pentax AirWay Scope (Pentax Corporation, Tokyo, Japan) was found to be superior to the Macintosh in terms of first-pass success (OR 7.98 (95%CrI 1.06–73.00)). Of note, this review did not consider the effect of different devices on cervical spine movement or SAC, nor the occurrence of neurological complications. In addition, only one study involved the emergency tracheal intubation of patients with traumatic injuries, with most studies excluding patients who were predicted as being difficult tracheal intubations. Thus, the generalisability of these findings to the clinical setting is limited.

The use of a bougie results in a higher first-attempt tracheal intubation success rate in the presence of cervical immobilisation compared with an intubating stylet (100% (95%CI 93–100) vs. 78% (95% 61–90%)) [18]; in this study, 53% of tracheal intubations were done using direct laryngoscopy.

Cricoid force

The use of cricoid force is common in patients undergoing emergency tracheal intubation. The effectiveness of cricoid force in minimising the risk of pulmonary aspiration of gastric contents remains a contentious issue, with a lack of evidence supporting its use [19, 20]. Given this, it is essential to ensure that the application of cricoid force does not have adverse effects. With respect to the cervical spine, two

cadaveric studies have shown that correctly applied cricoid force has a minimal effect on cervical spine alignment. Using fluoroscopy and lateral imaging, Donaldson et al. showed that cricoid force caused a similar amount of cervical spine movement as tracheal intubation in cadavers with a C5/6 injury [21]. Prasan et al. also used cadavers with a C5/6 injury and although SAC was not assessed, they did use an electromagnetic motion analysis device to measure changes in bony alignment in three dimensions [22]. They found that cricoid force had minimal effect on the cervical spine, with the minimal displacement observed being < 3°. Overall, there is very limited evidence (10 cadavers in total and only a single fracture level studied) supporting the safety of cricoid force in patients with cervical spinal injury. As such, anaesthetists should consider the risks and benefits of its application during their planning of airway management.

Direct and indirect laryngoscopy

A recent Cochrane review found that all types of videolaryngoscope (Macintosh-style, hyperangulated and channelled) were likely to reduce the risk of failed tracheal intubation and increase the chance of first-attempt success compared with direct laryngoscopy [23]. Although 25 of the 222 studies identified did use a cervical collar or MILS to simulate a difficult airway, these were not analysed separately and thus the findings are difficult to extrapolate to patients with cervical spine injury. In addition, there was no assessment of post-procedural neurological injury among the airway complications considered.

Only four other relevant studies were identified, just one of which assessed changes in SAC. Inan et al. compared tracheal intubation using a Macintosh laryngoscope with the LMA® Fastrach (Teleflex Medical Europe Ltd., Athlone, Ireland) and LMA® CTrach (Teleflex Medical Europe Ltd) in patients undergoing elective cervical spinal surgery [24]. Patients with cervical trauma or injury were not studied. No

cervical immobilisation was used and the glottic view targeted was not stated. Only two-dimensional lateral fluoroscopic changes in angulation were measured. Cervical angulation at C1/2 was similar for all devices, but the LMA CTrach reduced cervical spine extension at C3 compared with the LMA Fastrach and Macintosh blade (0.7° vs. 3.7° and 7.1°, respectively). However, there were failures to intubate the tracheas with the LMA Fastrach (n = 5) and LMA CTrach (n = 1); all tracheal intubations with the Macintosh blade were successful.

A randomised crossover trial of 20 patients with their cervical spine immobilised by a semi-rigid collar, compared tracheal intubation using a Macintosh blade with C-MAC D-blade videolaryngoscope [25]. No patients had traumatic injury to the spine and best possible glottic view was achieved during direct laryngoscopy. The C-MAC D-blade produced less cervical spine movement at C0–C1 compared with direct laryngoscopy on lateral fluoroscopic imaging (mean (SD) 6.8 (5.0)° vs. 12.1 (4.2)°); movement was similar for both devices at C1–2 and C2–C5.

Romito et al. using a cadaveric model with maximal surgically created cervical spine instability to compare four devices: Macintosh blade; GlideScope; C-MAC D-Blade; and McGrath MAC X-blade (Medtronic Limited, Watford, UK) [26]. Cervical immobilisation was achieved using Mayfield tongs. Displacement was measured using lateral radiographs. All the videolaryngoscopes caused a similar degree of displacement at all cervical spine segments (C1–C6) and with significantly less than that seen with the Macintosh laryngoscope. All glottic views achieved with the Macintosh blade were Cormack–Lehane grade 3 or 4.

A second cadaveric study assessed changes in dural sac width using myelography during tracheal intubation [27]. While not a direct measure of SAC, this does assess changes in vertebral canal diameter and is the most clinically relevant method to assess the risk of spinal cord impingement during tracheal intubation. Atlanto-occipital dislocation was created surgically in six cadavers and then tracheal intubation was undertaken using a Macintosh blade and King Vision aBlade videolaryngoscope (Ambu). No cervical immobilisation was applied. Direct laryngoscopy caused a median (range) reduction in dural sac width of 1.6 (0.6–1.9) mm compared with 0.9 (0.6–1.1) mm with the King Vision aBlade. Other measures of cervical spine movement were similar for both devices.

Flexible bronchoscope-guided tracheal intubation

Historically, flexible bronchoscope-guided tracheal intubation was considered by many as the gold standard for patients with cervical spine injuries. This was in part due to

the ability to undertake this with the patient awake, thereby allowing neurological assessment after tracheal intubation and before induction of general anaesthesia. A systematic review from 2019 was unable to identify any study that had compared awake vs. non-awake tracheal intubation [28]. A more recent randomised controlled trial compared awake tracheal intubation in patients with upper cervical spine instability using a flexible bronchoscope with the McGrath videolaryngoscope [29]. Only lateral measurements of angulation were assessed radiographically. At C1/2, changes in angulation were greater with videolaryngoscopy but at C3 movement was similar. There were no new motor deficits in any patients following tracheal intubation. At present, the precise benefits of awake tracheal intubation in the context of cervical spine injury are uncertain and more research is needed.

With the advent of videolaryngoscopes, there has been a move towards this becoming the default technique in many centres [6]. A randomised crossover trial compared asleep flexible bronchoscope-guided tracheal intubation via a LMA-Fastrach with the C-MAC videolaryngoscope [30]. This showed a small reduction in movement at C0/C1 and C1/C2 levels with the use of the flexible bronchoscope technique. However, this did not assess SAC and only made radiographic measurements of change in angulation. In addition, the use of a supraglottic airway may not be possible in the emergent setting where patients are often not fasted. A randomised controlled trial compared asleep flexible bronchoscope-guided tracheal intubation with the Airtraq videolaryngoscope in 40 patients with a traumatic cervical spine fracture undergoing surgical fixation [31]. This study is one of the few to have directly assessed the effect of tracheal intubation on the spinal cord, in this case by monitoring for alterations in somatosensory evoked potentials (SSEPs). All patients underwent tracheal intubation in a cervical collar. Only one patient in each group experienced significant changes in SSEPs and this was not associated with any deterioration in neurology postoperatively. Of note, patient positioning was associated with a much higher incidence of alterations in SSEPs compared with tracheal intubation. Tracheal intubation was successful in all patients and subjective ease of intubation was the same in both groups. This suggests that videolaryngoscopy may be an appropriate alternative to flexible bronchoscope-guided tracheal intubation.

Risk of tracheal intubation

The risk of secondary spinal cord injury during tracheal intubation is unknown but is likely to be overestimated. Part of the difficulty in determining the degree of risk is due to

the natural history of delayed neurological deterioration in spinal cord injuries [32]; this is why the degree of neurological impairment after spinal cord damage is usually determined at 72 h following injury. There are several mechanisms underlying this acute secondary spinal cord injury including: ischaemia secondary to vascular injury; excitotoxic cascades with pro-inflammatory cytokines, chemokines, auto-antibodies and free radical formation; calcium influx; oedema; and ultimately axonal degeneration and demyelination [33]. Due to a move towards undertaking early surgical intervention for traumatic cervical spine injury (within 24–72 h) [34], patients will often have their tracheas intubated during the acute phase of evolving secondary spinal injury. This may result in an incorrect correlation between this and later neurological deterioration, despite the lack of evidence of direct causation.

A meta-analysis identified nine studies that reported neurological complications after tracheal intubation in patients at risk of cervical cord injury (definitions varied between different studies) [28]. Overall, there were 4/1177 (0.34%) cases of postoperative neurological deterioration: one case involved upper limb numbness which spontaneously resolved; and there were no details provided as to the nature, severity and duration of the symptoms for the other cases.

Detailed analysis of cases of neurological deterioration after tracheal intubation has not shown a direct causative effect [35]. An analysis of 841 litigation claims against the NHS in England from 1995 to 2007 listed one case of cervical spine trauma with a severe/fatal outcome, but no other details were provided [36]. This analysis was repeated for the period 2008–2018 (1230 claims) with no incidents of neurological injury after tracheal intubation reported [37]. A review of cervical cord injuries in the American Society of Anesthesiologists Closed Claims database identified 37 cases from 1970 to 2007 of which 33 resulted in quadriplegia or paraplegia [38]. Of note, 28 patients who suffered cervical cord injury were judged to have anatomically stable spines pre-operatively. Most patients who developed cord injury underwent intubation of their trachea ($n = 36$) and this involved direct laryngoscopy in the majority of cases ($n = 30$). Among the nine patients with an unstable cervical spine who developed spinal cord injury, airway management was judged to have possibly been a contributory factor in two cases; however, this was done solely on the basis that tracheal intubation was difficult and cervical immobilisation had not been used during intubation. Although this suggests that peri-operative spinal cord injury is rare, it should be noted that the

American Society of Anesthesiologists Closed Claims database only reviews < 5% of all critical incidents.

Discussion

This review has highlighted the continuing uncertainty regarding the optimal technique(s) for airway management in patients with confirmed or suspected injury to their cervical spine. In addition, the degree of risk of causing secondary spinal cord injury remains unknown. All airway interventions are associated with some degree of movement of the cervical spine; in general, these are very small and whether these are clinically significant in terms of impingement of the spinal cord is unclear. This uncertainty precludes making clear guidelines to assist clinicians in their clinical practice. It is likely that many practices will continue purely on the basis of the precautionary principle. The challenges of applying the precautionary principle to clinical practice are beyond the scope of this article, but it should be remembered that measures applied on this basis “*must not be disproportionate to the desired level of protection and must not aim at zero risk*” [39].

It is important to make some general comments regarding the methodology and limitations of much of the research in this area. Due to ethical concerns and practical difficulties, most of the research involving tracheal intubation and cervical spinal cord injury was done using healthy volunteers with uninjured cervical spines or cadavers with surgically created cervical spinal injury. The cadaveric models of instability involve the complete transection of the majority of supporting ligaments of the cervical spine, which is an injury that would be associated with a high immediate mortality rate if caused by trauma in the real world-setting. In addition, the most common endpoints for studies involving tracheal intubation are measures of procedural ease, such as success rate, time to intubation, glottic view and intubation difficulty score. While success rate is an important clinical metric, the others are not of importance to patients or clinicians; the primary concern in this population is the (potential) risk of causing secondary spinal cord injury, and thus outcomes need to be focused on this. Many previous studies have chosen to use surrogate measurements of bony cervical spine movement, usually changes in external angulation that are made in two-dimensional planes, to assess the effect of airway manoeuvres on the cervical spine. These measurements may not be reflective of changes in cervical spinal canal diameter, which will be the best determinant of the risk of spinal cord impingement. Cervical spinal canal diameter is more accurately assessed by examining changes in SAC (Fig. 1) but unfortunately this outcome measure is used

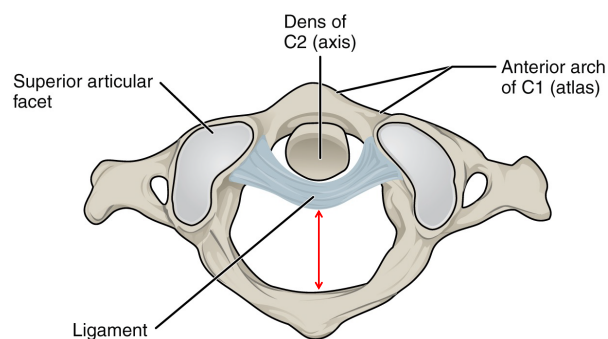


Figure 1 The atlantoaxial joint is formed from the dens portion of the axis (C2 vertebra) and the anterior arch of the atlas (C1 vertebra), with the dens held in place by the transverse ligament. The red arrow illustrates the space available for cord. From OpenStax book *Anatomy and Physiology*, available at <https://openstax.org/details/books/anatomy-and-physiology>.

infrequently (Table 2) [10, 27, 40–44]. Future research in this area needs to focus on outcomes such as vertebral canal dimension and SAC. In addition, clinicians who are intubating the trachea often target maximal glottic exposure

at laryngoscopy. This is not reflective of current clinical practice where minimal glottic exposure, that is just sufficient to allow tracheal intubation, is a more typical goal. In addition, there is a lack of long-term follow-up in most patient studies which precludes determination of the incidence of late neurological deterioration following tracheal intubation. These factors combine to make extrapolation of many research studies to clinical practice challenging. There has been a move towards standardisation of outcome measures in peri-operative trials although, at present, airway research has not been included [45]; the addition of standardised, patient-centred, clinical important outcomes to these guidelines is likely to improve the quality of future research studies in this area.

The available published research does not support any technique being considered as a gold-standard approach for tracheal intubation. This has important clinical implications, as clinicians may feel pressured to use a particular technique due to fear of criticism and/or medicolegal implications [46]. This was illustrated in an international survey in which practitioners (including non-medically qualified clinicians in low- and medium-income

Table 2 Studies that radiologically measured space available for cord during tracheal intubation.

Study	n	Type of study	Subjects	Injury	Glottic view	MILS	Vertebral canal measurement	Spine level(s) studied	Intubating devices
Donaldson et al. [10]	6	Non-randomised before-and-after	Cadavers	Type-2 odontoid fracture (surgical)	“Gentle laryngoscopy”	Yes	Anterior–posterior on lateral radiograph	C1/2	Direct laryngoscopy* vs. blind nasal intubation
Mentzelopolous et al. [44]	8	Randomised cross-over	Healthy volunteers	None	Minimal glottic exposure	No	Anterior–posterior on lateral radiograph	C0/1; C1/2; C2/3; C3/4; C4/5	Macintosh 4 vs. balloon laryngoscopy
Hindman et al. [42]	14	Randomised cross-over	Cadavers	Type-2 odontoid fracture (surgical)	Best possible view	No	Anterior–posterior on lateral radiograph	C1/2	Macintosh 3 vs. Airtraq 3
McCahon et al. [43]	6	Randomised cross-over	Cadavers	Type-2 odontoid fracture (surgical)	Minimal glottic exposure	Yes	Anterior–posterior on lateral radiograph	C1/2	Macintosh 3 vs. McCoy 3 vs. Airtraq 3
Hindman et al. [41]	14	Randomised cross-over	Cadavers	Severe (stage 4) C3/4 injury	Best possible view	No	Anterior–posterior on lateral radiograph	C3/4	Macintosh 3 vs. Airtraq 3
Liao et al. [27]	6	Non-randomised cross-over	Cadavers	Atlanto-axial dislocation	Not stated	No	Anterior–posterior on lateral radiograph plus myelogram to assess width of dural space	C0/1	Macintosh 3 vs. King Vision aBlade videolaryngoscope vs. Laryngeal Tube
Weilbacher et al. [40]	6	Randomised cross-over	Cadavers	Atlanto-axial dislocation	Not stated	No	Anterior–posterior on lateral radiograph	C0/1; C1/2	Macintosh 3 vs. Combitube

*Blade size not stated. MILS, manual in-line stabilisation.

countries) were asked for their preferred tracheal intubation technique for a hypothetical scenario involving cervical spinal instability [47]. Around 25% of respondents who stated they did not have flexible bronchoscopes available in their hospital still expressed a preference for an awake technique using a flexible bronchoscope. Similarly, 23–27% of clinicians without easy access to videolaryngoscopes opted for this technique. This lack of consensus is mirrored in other surveys of clinical practice. In a survey undertaken by the American Society of Anesthesiologists, for a haemodynamically stable patient with neurological symptoms after cervical spine injury, respondents favoured a flexible bronchoscope-guided technique and then videolaryngoscopy for tracheal intubation. However, in the presence of haemodynamic instability, videolaryngoscopy and direct laryngoscopy were preferred [48]. A survey of intensive care physicians based in Canada found that direct laryngoscopy was the first-choice approach for the intubation of the trachea of a patient who was critically ill and still had cervical immobilisation in place [49].

On the basis of the research findings identified by this review article, it is not possible to make strong recommendations for clinical practice. Simple airway manoeuvres appear to cause a greater degree of cervical spine movement than tracheal intubation. However, these are often required urgently in patients with acute traumatic injuries to maintain a patent airway and avoid hypoxaemia. Given the lack of effective cervical spinal immobilisation by MILS, its continued use in clinical management should be questioned; it is one of the few airway interventions that anaesthetists routinely practise that will increase the incidence of difficult and failed tracheal intubation. This, in turn, risks exposing a damaged, vulnerable cervical spinal cord to a further hypoxic insult which may worsen any neurological injury as this may provoke an excitotoxic cascade leading to neuronal cell apoptosis and necroptosis [33]. The application of MILS also increases the maximal force transmitted during laryngoscopy [50]. If MILS is used, then the use of certain videolaryngoscopes may increase tracheal intubation first-pass success, although the evidence of clear superiority of these devices over direct laryngoscopy with a Macintosh blade is lacking. The use of a bougie may also increase the chance of successful tracheal intubation if MILS is used.

With respect to tracheal intubation itself, there is no clear evidence of any benefit for awake techniques in terms of prevention of secondary spinal cord injury. Similarly, there is a paucity of published data to support the notion that flexible bronchoscope-guided tracheal intubation is the gold-standard technique. Videolaryngoscopy appears

to cause a similar degree of cervical spine displacement and is an appropriate alternative approach. This is important in the emergency setting and in patients with multiple injuries, in whom a rapid sequence induction may be clinically indicated.

Videolaryngoscopy is likely to reduce the risk of failed tracheal intubation and increase the chance of first-attempt success compared with direct laryngoscopy; this alone may be enough of a reason for clinicians to adopt this as their default technique. However, it is more uncertain as to whether there are benefits with videolaryngoscopy in terms of degree of cervical spine displacement. The evidence in this regard is more limited but direct laryngoscopy does appear to cause a slightly greater degree of cervical spinal movement during tracheal intubation. This is not to say that direct laryngoscopy increases the risk of spinal cord injury, as the studies that have measured SAC in this regard have shown only minor differences between different devices. In cadaveric models of C3/C4 injury and type-2 odontoid peg fracture, there was no difference in the change in SAC with a Macintosh blade and the Airtraq videolaryngoscope [41–43]. Yet, in a cadaveric model of atlanto-occipital instability, the King Vision aBlade did produce a smaller change in SAC compared with a Macintosh blade [27]. The significance of this minor degree of additional (potential) spinal cord compression in terms of the risk of secondary spinal cord injury in the clinical setting is unknown. In addition, there is a lack of research in this area using more modern videolaryngoscopes and hyperangulated blades.

The true risk of secondary spinal cord injury during airway management remains unknown. Given the complex patient population involved, this will not be accurately determined from analysis of randomised controlled trials. National airway databases and/or registries are likely to provide the most accurate data [51], and the addition of new spinal cord injury as an airway complication would be helpful in this regard. From the data already published, the risk of spinal cord injury during tracheal intubation appears to be very low even in the presence of gross cervical spine instability. It should also be noted that the maximal insult to the spinal cord occurs at the moment of injury; the force required to cause cervical fractures and disruption of ligaments is 645–7429 N (depending on the force vector) [52]. In comparison, the mean (SD) force applied during direct and videolaryngoscopy (Airtraq) is 49 (16) N and 10 (3) N, respectively [53]. Within the cervical spine's normal range of motion, movement requires very little force and is therefore unlikely to transfer significant energy to the spinal cord; this is further attenuated by the absence of the wave

effect seen in trauma that occurs focusing the force [54]. Any force applied during laryngoscopy is also only applied typically for around 10–20 s; animal models have suggested that > 30 min of cord compression is needed to cause sustained spinal cord injury [55].

In conclusion, I have found little evidence to suggest that laryngoscopy for tracheal intubation in patients with cervical spine injury is likely to cause secondary spinal cord injury. There are also insufficient data to suggest that the use of videolaryngoscopy or fiberoptic bronchoscope-guided tracheal intubation confers any advantage in this regard. Videolaryngoscopy does reduce the incidence of failed tracheal intubation especially if MILS is used. However, the continued routine use of MILS during tracheal intubation should be challenged given the lack of evidence of spinal stabilisation and the increased incidence of difficult and failed tracheal intubation. As such, in patients with traumatic injury I would recommend that clinicians use the tracheal intubation technique with which they are most proficient and that is most likely to minimise cervical spine movement in that particular patient and clinical setting. This choice may vary between clinicians and the uncertainty as to what is optimal practice should be reflected in published guidelines. Future research in this area should focus on the use of clinically important outcome measures (such as SAC) with the use of newer videolaryngoscopes and hyperangulated blades.

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Supporting Information

Additional supporting information may be found online via the journal website.

Appendix S1. Full details of search strategies in each database.