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Guidelines

Airway management in patients with suspected or confirmed cervical spine injury

Guidelines from the Difficult Airway Society (DAS), Association of Anaesthetists (AoA), British Society of Orthopaedic Anaesthetists (BSOA), Intensive Care Society (ICS), Neuro Anaesthesia and Critical Care Society (NACCS), Faculty of Prehospital Care and Royal College of Emergency Medicine (RCEM)

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Summary

Background There are concerns that airway management in patients with suspected or confirmed cervical spine injury may exacerbate an existing neurological deficit, cause a new spinal cord injury or be hazardous due to precautions to avoid neurological injury. However, there are no evidence-based guidelines for practicing clinicians to support safe and effective airway management in this setting.

Methods An expert multidisciplinary, multi-society working party conducted a systematic review of contemporary literature (January 2012–June 2022), followed by a three-round Delphi process to produce guidelines to improve airway management for patients with suspected or confirmed cervical spine injury.

Results We included 67 articles in the systematic review, and successfully agreed 23 recommendations. Evidence supporting recommendations was generally modest, and only one moderate and two strong recommendations were made. Overall, recommendations highlight key principles and techniques for pre-oxygenation and facemask ventilation; supraglottic airway device use; tracheal intubation; adjuncts during tracheal intubation; cricoid force and external laryngeal manipulation; emergency front-of-neck airway access; awake tracheal intubation; and cervical spine immobilisation. We also signpost to recommendations on pre-hospital care, military settings and principles in human factors.

Conclusions It is hoped that the pragmatic approach to airway management made within these guidelines will improve the safety and efficacy of airway management in adult patients with suspected or confirmed cervical spine injury.

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Recommendations

1. Attempts should be made to minimise cervical spine movement during pre-oxygenation and facemask ventilation (Grade D; weak recommendation).
2. When a simple manoeuvre is required to maintain an airway, jaw thrust should be used rather than head tilt plus chin lift (Grade D; weak recommendation).
3. If tracheal intubation through a supraglottic airway device (SAD) is indicated, there is no specific device that is clearly superior in reducing cervical spine movement or successful tracheal intubation. Clinicians should use supraglottic airway devices that are familiar and available to them (Grade D; strong recommendation).
4. Second-generation SADs should be considered in preference to first-generation SADs (Grade D; strong recommendation).
5. Where possible, videolaryngoscopy should be used for tracheal intubation in patients with suspected or confirmed cervical spine injury (Grade A; moderate recommendation). We are unable to recommend a particular type of videolaryngoscope or a specific type of blade.
6. Clinicians who perform tracheal intubation in patients with suspected or confirmed cervical spine injury should receive regular training in the use of videolaryngoscopy with cervical spine immobilisation (Grade D; weak recommendation).
7. Clinicians should consider using an adjunct such as a stylet or bougie when performing tracheal intubation in a patient whose cervical spine is immobilised (Grade D; weak recommendation).
8. During tracheal intubation attempts, a semi-rigid or rigid cervical collar should be removed, which can be done most easily by only removing the anterior part of the collar; this will also help minimise any movement to the cervical spine (Grade D, weak recommendation).
9. Multidisciplinary planning, preparation and optimisation of human factors should be considered before airway management in patients with suspected or confirmed cervical spine injury (Grade D; weak recommendation).

Why were these guidelines developed?

Despite a lack of supporting evidence, airway management in patients with suspected or confirmed cervical spine injury is traditionally thought to increase the risk of worsening existing neurological deficits (secondary spinal cord injury) or risk of causing a new spinal cord injury (primary spinal cord injury). Although there has been evidence synthesis for specific elements of airway management in this setting, there has been little guidance to support clinical decision-making for airway management in this cohort of patients.

What guidelines currently exist?

Several guidelines exist for airway management in a variety of clinical settings (including trauma) but there are none that are specific for airway management in patients with suspected or confirmed cervical spine injury.

How do these guidelines differ from existing guidelines?

These guidelines focus on the impact of airway management on cervical spine-related safety outcomes rather than efficacy of different airway management techniques. Whilst these two are related, the primary aim is to support clinicians in performing airway management whilst minimising the risk of airway complications and cervical spine cord injury.

Introduction

In Europe over 30,000 people per year have a traumatic injury to their spine; in around 25% of these patients, there is an associated injury to the spinal cord resulting in a neurological deficit [1]. In the context of major trauma, < 2% of patients suffer a spinal cord injury, with the cervical cord injured in around 45% [2]. It is not possible to determine accurately the incidence of injuries to the cervical spine which are `unstable´, due to a lack of consensus regarding the definition of instability [3].

Patients with suspected or confirmed cervical spine injury often require airway management. This may be as part of their initial resuscitation in the emergency department or to facilitate surgical management of their injuries during their hospital admission. Clinicians are often concerned that airway management may exacerbate an existing neurological deficit or cause a new spinal cord injury, or indeed be particularly hazardous due to precautions to avoid neurological injury. This is despite a paucity of evidence linking spinal cord injury to airway management [4]. A meta-analysis including 1177 patients with cervical spine cord injury who underwent surgical fixation (and thus required intubation of their trachea) showed a postoperative neurological complication rate of 0.34% [5]: one case involved upper limb numbness which resolved spontaneously; no details were provided for the remaining cases in terms of nature, severity or duration of symptoms. The risk of secondary spinal cord injury (e.g. due to tracheal intubation or patient movement/positioning) is unknown. This is in part due to the delayed neurological deterioration that occurs in 2–10% of spinal cord injuries even in the absence of a clear causative factor [6]. This may result in the incorrect correlation between airway interventions and later neurological deterioration, despite a lack of direct evidence of causation [7].

The optimal techniques for airway management that will minimise any associated cervical spine movement remain controversial, with a lack of high-quality evidence supporting any one technique. Historically, awake tracheal intubation (ATI) was often considered the gold standard in terms of minimisation of cervical spine movement, but the advent and ubiquitous availability of videolaryngoscopy has seen this approach become more common [8]. In addition, ATI is frequently impractical due to a variety of factors including: requirement for time-critical interventions for associated traumatic injuries; tracheal intubation in settings outside of operating theatres e.g. emergency departments or pre-hospital environments; and patient non-compliance e.g. secondary to acute intoxication or traumatic brain injury.

Given the heterogeneity of patients who require intervention after trauma, there is no single airway management approach that could be applied in all situations. Clinicians are likely to need to tailor their approach to airway management using the most appropriate technique(s) for each individual patient. However, there remain no clear evidence-based guidelines for practicing clinicians regarding airway management in adult patients with suspected or confirmed traumatic cervical spine injury. We aimed to produce pragmatic clinical guidelines through a review of the evidence conducted by speciality experts.

Methods

We developed these guidelines in accordance with best practice recommendations [9, 10] including the Appraisal of Guidelines for Research and Evaluation 2 (AGREE-2) reporting checklist [11]. Supporting organisations included the Difficult Airway Society (DAS); Association of Anaesthetists (AoA); British Society of Orthopaedic Anaesthetists (BSOA); Intensive Care Society (ICS); Neuro Anaesthesia and Critical Care Society (NACCS); Faculty of Prehospital Care; and Royal College of Emergency

Medicine (RCEM). The work was delivered by a multidisciplinary working party, with representation from relevant medical specialities (anaesthesia, intensive care, emergency medicine, spinal surgery), operating department practitioners, doctors in training and patients.

Evidence to inform recommendations was sought by conducting a systematic review of the literature in accordance with PRISMA recommendations [12]. We searched the PubMed, Embase and MEDLINE databases using controlled vocabulary and free text terms in assorted permutations combined with Boolean operators to develop a search strategy to include relevant studies (see Online Supporting Information Appendix S1). The search was limited to January 2012–June 2022 to ensure contemporary evidence was included, given a multitude of changes to clinical practice in the years leading up to 2012. However, studies deemed to be of significant implication to current practice published before this epoch, and others not identified through the literature search (including hand-searching and review of references of included studies), were also included. We sought studies investigating the impact of any element of airway management in the setting of suspected, confirmed or simulated cervical spine injury in adults (age ≥ 16 years), or non-clinical data assessing the impact of airway manoeuvres on cervical spine movement or cervical spine immobilisation on airway management outcomes. The settings of the studies included in-hospital; pre-hospital; or military. Airway management interventions included facemask ventilation; supraglottic airway device (SAD) use; tracheal intubation; front-of-neck airway; pre- or per-oxygenation; rapid sequence induction (RSI); cricoid force; or any other airway procedure deemed relevant. We included randomised controlled trials; systematic reviews with meta-analyses; bench studies; and cadaveric studies in English language with full texts available. Titles, abstracts and full texts were screened by two authors (HAI and KE) using Rayyan software (Rayyan Systems, Boston, MA, USA), and three authors (HAI, KE and MDW) extracted data onto a standardised spreadsheet (Microsoft Excel; Microsoft, Inc., Redmond, WA, USA). Data included study characteristics; interventions of interest; and outcomes relevant to the topic of interest. Data were synthesised qualitatively, and only studies included in formulating recommendations underwent risk of bias assessment using either the Cochrane risk of bias 2 tool [13] or the Newcastle–Ottawa Scale [14].

Recommendations were made using data from included studies and, in the absence of sufficient evidence, by expert opinion from 12 authors. Recommendations underwent a three-round Delphi approach to assess the content, clarity and importance of each recommendation. Using a standardised Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, WA, USA) recommendations were rated anonymously by all authors as `accept´, `reject´ or `revise´, as well as whether each recommendation should be a `top 10´ recommendation. Two rounds of remote rating were performed, and the final list presented at a virtual round table for discussion, final voting and ratification (where required).

Recommendations were graded using the modified Centre for Evidence-based Medicine tool (A to E) based on available evidence [15] (see online Supporting Information Table S1), and strength of recommendation judgements made by the expert panel based on analysis of the evidence and consensus voting and discussion through the Delphi process. Agreement with a statement by ≥ 75% of the panellists was the threshold for consensus agreement.

Results

For the systematic review, a total of 67 articles were included (see online Supporting Information Figure S1), comprising 21 randomised controlled clinical trials, 11 cadaveric studies, 10 observational studies, eight crossover studies, seven systematic reviews, five guidelines, two narrative reviews, one case report, one correspondence and one editorial. Risk of bias assessments for clinical trials are reported in online Supporting Information Appendices S1–S3. Results from all included studies relevant to this work are reported in the online Supporting Information Appendix S4.

In the first two Delphi rounds, all 12 invitees participated. In the final Delphi round table, seven invitees participated. The full results of each Delphi round, and the areas in which clinical consensus could not be achieved, are reported in the online Supporting Information Appendix S5. Through the process, it became apparent that the methodology and scope of work were not suitable to make robust recommendations in the setting of elective surgery, prehospital and military medicine, which we then excluded. For similar reasons, we also did not make recommendations on the use of cricoid force, pre-oxygenation techniques and emergency front of neck airway.

Pre-oxygenation and facemask ventilation

Facemask ventilation is associated with more cervical spine movement than other airway management manoeuvres [16]. Historical data suggest that this may be contributed to by head tilt and chin lift positioning used to open the airway [17]. More recently, Sawada et al. studied the effect of a two-handed jaw thrust on cervical vertebral movement in 20 non-obese, healthy patients [18]. This technique resulted in no significant change in anterior movement and small changes in intervertebral angulation (mean (SD) 3.2° (3.0°)) at C0–C4. These measurements were assessed using lateral static radiographs and no assessment of space available for cord (SAC) was made. Prasarn et al. compared head-tilt plus chin lift with a jaw thrust manoeuvre in a cadaveric model with an unstable C1–C2 injury (odontoid type-2 fracture) [19]. Cervical segment movement was measured using 3D electromagnetic motion analysis. Compared with a jaw thrust, head tilt with chin lift resulted in significantly more flexion-extension, axial rotation and lateral bending (mean (SD) 14.7° (6.1) vs. 4.8° (2.7), 5.4° (2.8) vs. 2.4° (1.3) and 7.4° (4.0) vs. 2.5° (2.2), respectively). These results support an earlier cadaveric study with an identical injury that showed that jaw thrust maintained SAC to a greater degree than chin lift (mean (SD) 1.6 (0.8) mm vs. 1.1 (1.0) mm) [20].

High-flow nasal oxygen (HFNO) for pre- and peroxygenation is used increasingly due to the benefits of apnoeic oxygenation [21] and is recommended for ATI [22]. However, there are minimal data on its use in patients with suspected or confirmed cervical spine injury. Reports of HFNO-induced pneumocephalus in the context of base of skull fracture can be found in the literature [23], warranting caution in patients who may present with multiple injuries which are difficult to fully establish before tracheal intubation.

Overall, there is a dearth of robust evidence on the use of facemask and HFNO in patients with suspected or confirmed cervical spine injury, and more research is required.

- **Attempts should be made to minimise cervical spine movement during pre-oxygenation and facemask ventilation (Grade D; weak recommendation).**
- **When a simple manoeuvre is required to maintain an airway, jaw thrust should be used rather than head tilt plus chin lift (Grade D; weak recommendation).**
- **The use of HFNO may be considered for peroxygenation in patients with cervical spine injuries but should be used with caution in patients with suspected or confirmed base of skull fractures (Grade D; weak recommendation).**

Supraglottic airway devices

A wide range of supraglottic airway devices (SADs) have been assessed for their impact on cervical spine movement and their performance with cervical spine immobilisation in patients and cadavers. Most first- and second-generation SADs studied perform either equally well or better when cervical spine immobilisation is in place, with little data showing the superiority of one device over another [24–27]. Cervical spine immobilisation, therefore, does not hamper SAD effectiveness in terms of ventilation.

Tracheal intubation through SAD has been examined extensively; however, most studies assess efficacy of tracheal intubation devices (e.g. success rates), rather than safety (cervical spine movement). Tracheal intubation through an LMA® Fastrach™[1] (Teleflex Medical Europe Ltd., Athlone, Ireland) is associated with similar success rates when compared with McCoy laryngoscopy (Penlon, Oxford, UK), the perilaryngeal airway (CobraPLA®; Engineered Medical Systems, Indianapolis, IN, USA) or LMA CTrach™ (Teleflex Incorporated) or Glidescope® (Verathon, Bothell, WA, USA) [28–31], lower success rate when compared with C-MAC® (Karl Storz SE & Co. KG, Tuttlingen, Germany) [32], and greater success rate than tracheal intubation through a LMA Classic™ (Teleflex Incorporated) [33]. There were no clinically important differences between other supraglottic airway devices and means for achieving tracheal intubation [34, 35].

When assessing cervical spine movement, Inan et al. compared radiographic evidence of cervical spine movement with during tracheal intubation using the LMA CTrach, LMA Fastrach and Macintosh laryngoscope [36]. They found that there was less movement with the LMA CTrach compared with the other two devices at C2/3, but no differences in movement at C1/2. However, any differences were modest and of uncertain clinical importance.

Jakhar et al. assessed head movement in patients with simulated cervical spine immobilisation with manual in-line stabilisation (MILS) [32]. They found that gross head movement measured with a goniometer occurred with a greater frequency with C-MAC than with the LMA Fastrach (21% vs. 11%). However, the magnitude of this movement was unclear and therefore definitive conclusions cannot be drawn.

Sahin et al. assessed cervical spine movement radiologically in patients having their tracheas intubated for elective surgery with either LMA CTrach, C-MAC or direct laryngoscopy with a Macintosh blade. They reported that motion at all levels measured (C0–C3) was lower with the LMA CTrach, though the clinical significance of this was unclear [37].

Wendling et al. assessed cadaveric cervical spine movement during tracheal intubation with an Airtraq (Prodol Meditec S.A., Vizcaya, Spain), Lightwand (Bovie Aaron Medical, St. Petersburg, FL, USA), LMA Fastrach and

[1] LMA is a registered trademark of The Laryngeal Mask Company Ltd, an affiliate of Teleflex Incorporated.

Macintosh laryngoscope [38]. Whilst the Lightwand was associated with reduced flexion/extension movement at C1/2 compared with other devices, the clinical relevance of this was unclear. There were no differences when the Airtraq, LMA Fastrach and Macintosh laryngoscopes were compared.

Overall, the evidence base is modest for the implications of supraglottic airway device safety in the setting of suspected or confirmed cervical spine injury.

- **Supraglottic airway devices should be used according to airway management needs and not as an airway device for the purpose of reducing head and neck movement in patients with suspected or confirmed cervical spine injury (Grade C; weak recommendation).**
- **If tracheal intubation through a supraglottic airway device is indicated, there is no specific device that is clearly superior in reducing cervical spine movement or successful tracheal intubation. Clinicians should use supraglottic airway devices that are familiar and available to them (Grade D; strong recommendation).**
- **Second-generation SADs should be considered in preference to first-generation SADs (Grade D; strong recommendation).**

Tracheal intubation

There are some important factors to be considered when assessing cervical spine biomechanics during tracheal intubation. The first is that few studies assess changes in vertebral canal dimension (e.g. SAC). The vertebral canal is a three-dimensional structure that contains the spinal cord, and it is reduction in the size of this that will increase the risk of spinal cord impingement. Numerous studies used lateral radiographic measurements as a surrogate marker for vertebral canal dimension, but the clinical accuracy of this is unknown. Second, most studies use cadaveric models with surgically created spinal injuries. These typically involve the transection of the majority of supporting ligaments of the cervical spine, which is an injury that would normally be associated with a high immediate mortality rate and creates a level of instability that may not be encountered in clinical practice. Finally, there are no published data comparing the incidence of secondary spinal cord injury after tracheal intubation with different devices.

Liao et al. measured changes in dural sac width during tracheal intubation in a cadaveric model of atlanto-occipital instability [39]. Direct laryngoscopy with a Macintosh blade decreased dural sac width to a greater degree than videolaryngoscopy with the King Vision aBlade (Ambu, Bad Nauheim, Germany) (median (range) -0.5 (-0.7 to -0.3) mm to -1.6 (-1.9 to -0.6) vs. -0.4 (-0.9 to -0.1) to -0.9 (-1.1 to -0.6), respectively).

McCahon et al. assessed changes in SAC during tracheal intubation in a cadaveric model of atlanto-axial (type-2 odontoid peg fracture) instability [40]. During tracheal intubation, manual in-line stabilisation was used and the intubating clinician aimed for minimal glottic exposure to limit neck movement. The authors found no statistically different changes in SAC at C1/C2 level between the Airtraq and Macintosh laryngoscopes, or the Airtraq and McCoy laryngoscopes.

Romito et al. compared the Macintosh blade with three videolaryngoscopes (Glidescope, C-MAC D-Blade (Karl Storz SE & Co) and McGrath MAC X-blade (Medtronic, Minneapolis, MN, USA)) in two cadaveric models of severe cervical spinal instability [41]. Immobilisation of the cervical spine was achieved by Mayfield tongs and only external movement in cervical vertebral segments was measured (by lateral radiographs). At all levels from C1 to C5, the Macintosh blade resulted in the greatest amount of vertebral body displacement, and this was significantly greater than all three videolaryngoscopes. The videolaryngoscopes all produced similar degrees of vertebral body displacement. Of note, tracheal intubation was only successful in one of 16 attempts with the Macintosh blade compared with 100% success with the videolaryngoscopes.

There are several other studies comparing laryngoscopes, none of which directly assessed changes in vertebral canal dimension and relied on measurement of external angles. All suggested that smaller changes in cervical spinal segment angulation were seen when tracheal intubation was undertaken with the Truview (Truphatek International Ltd, Netanya, Israel) [42], GlideScope [43], McGrath [44], LMA CTrach [36] and C-MAC D-blade [45] compared with a Macintosh blade. Of note, rates of successful tracheal intubation with a Macintosh blade were worse (or at best equivalent) to the alternative devices.

Evidence of the superiority of videolaryngoscopy compared with direct laryngoscopy for several other efficacy and safety outcomes has been shown convincingly across a variety of clinical settings [46–48], underscoring the support for videolaryngoscopy in airway guidelines [49, 50]. Similarly, in patients with cervical spine immobilisation, several systematic reviews have reported the superiority of videolaryngoscopy and other video-assisted techniques over direct laryngoscopy [5, 51–53].

Overall, there are sufficient data to support the use of videolaryngoscopy for tracheal intubation, in particular given the increased first-pass successful intubation rate, especially when spinal immobilisation is maintained during attempts. However, there are no data to suggest that direct laryngoscopy is associated with a greater risk of secondary spinal cord injury, and more studies are needed that more accurately represent clinical practice.

- **Where possible, videolaryngoscopy should be used for tracheal intubation in patients with suspected or confirmed cervical spine injury (Grade A; moderate recommendation). We are unable to recommend a particular type of videolaryngoscope or a specific type of blade.**
- **Clinicians who perform tracheal intubation in patients with suspected or confirmed cervical spine injury should receive regular training in the use of videolaryngoscopy with cervical spine immobilisation (Grade D; weak recommendation).**

Adjuncts during tracheal intubation

A randomised controlled trial compared the effect of using a stylet within the tracheal tube for tracheal intubation using direct (Macintosh blade) and videolaryngoscopy (C-MAC) in patients having surgery for cervical myelopathy [54]. Patients who were predicted to be a difficult tracheal intubation were not studied, and MILS was used. The use of a stylet reduced the intubation difficulty score with laryngoscopy using the C-MAC, but not with the Macintosh blade. A stylet also reduced the requirement for a bougie and optimal external laryngeal manipulation for both devices. There was no difference in tracheal intubation success rate, number of attempts or incidence of complications (with the caveat that neurological complications were not recorded).

Goel et al. studied the use of three different stylet shapes as adjuncts for tracheal intubation using a C-MAC D-Blade videolaryngoscope [55]. Patients who were predicted to be a difficult tracheal intubation and patients with cervical spinal pathologies were not studied. Cervical spine immobilisation was simulated using a Philadelphia collar. Compared with not using a stylet, all the types of stylet formation increased the incidence of first-pass success and reduced the need for external laryngeal manipulation.

A large randomised controlled trial (n = 757) compared the use of a bougie with stylets in patients undergoing emergency tracheal intubation by emergency department residents [56]. The C-MAC videolaryngoscope was used for > 95% of tracheal intubations, but the video screen was only viewed during tracheal intubation in < 25% of cases, making the intervention more akin to direct rather than videolaryngoscopy. As this study involved emergency tracheal intubation, around 50% of the cohort had at least one predictor of difficult tracheal intubation. However, only 49/381 (13%) patients were allocated to the bougie group and 28/386 (7%) had their cervical spine immobilised during tracheal intubation. The use of a bougie increased first-pass success in patients with at least one difficult airway characteristic (96% vs. 82%; absolute difference 14% (95%CI 8–20%)). Similar benefits were seen with a bougie in those patients who had cervical immobilisation during tracheal intubation, with an absolute difference (95%CI) of 22% (9–36%).

In summary, there is limited evidence supporting the use of adjuncts with only two videolaryngoscopes studied. It appears that compared with no adjunct, the use of a stylet makes tracheal intubation using videolaryngoscopy easier and reduces the need for external manoeuvres. The study by Driver et al. suggests that a bougie is superior to a stylet in terms of first pass success rate for both direct and videolaryngoscopy; however, in this study tracheal intubation was not performed by anaesthetists and thus is difficult to extrapolate [56]. The effect of the use of adjuncts on cervical spine movement during tracheal intubation has also not yet been established.

- **Clinicians should consider using an adjunct such as a stylet or bougie when performing tracheal intubation in a patient whose cervical spine is immobilised (Grade D; weak recommendation).**

Cricoid force and external laryngeal manipulation

There is a paucity of quality evidence available on the use of cricoid force in patients with suspected or confirmed cervical spine injury. A single cadaveric study by Prasarn et al. examined the relative motion at C5–C6 as cricoid force was applied [57]. Variables studied were manual posterior cervical support (with and without) and force level applied (20 N or 40 N). There were no significant differences in motion at the C5–C6 injured segment with application of 20 N or 40 N of anterior pressure. The largest displacement observed was in flexion/extension (mean (SD) 2.95° (1.65°)), with manual posterior cervical support reducing this to 1.43° (0.65°).

We only identified a single study examining external laryngeal manipulation [58]. This randomised crossover trial studied the effects of external laryngeal manipulation on cervical spine motion during videolaryngoscopic tracheal intubation with MILS. However, patients with predicted difficult airways or cervical spine disease were excluded. Significantly less cervical spine motion occurred at the occiput-C1 segment during tracheal intubation with external laryngeal manipulation than without (35.7% reduction, mean difference (98%CI) -4.1° (-5.8° to -2.3°)). Additionally, the cervical spine angle during tracheal intubation was significantly smaller with external laryngeal manipulation than without at occiput-C1 (98% CI -4.4° to -0.8°; $p = 0.001$) and C2–C5 (98% CI -4.9° to -0.5°; $p = 0.004$).

The limited evidence makes it difficult to advocate for or against the use of cricoid force or external laryngeal manipulation. Overall, the evidence base is limited for these manoeuvres in patients with suspected or confirmed cervical spine injury. However, if clinicians decide to use cricoid force, several techniques may be beneficial for patient safety.

- **If cricoid force is used, it should be carried out by individuals who have received appropriate training (Grade D; weak recommendation).**
- **If difficulty in tracheal intubation is encountered when cricoid force is used, it should be removed (Grade D; weak recommendation).**
- **If laryngeal injury is suspected, cricoid force should be avoided (Grade D; weak recommendation).**
- **Cautious external laryngeal manipulation may be used to improve glottic view during tracheal intubation (Grade D; weak recommendation).**

Emergency front-of-neck airway access

Barnard et al. performed a prospective multicentre observational study assessing cricothyroidotomy performed in pre-hospital combat settings [59]. Their cohort had 34 patients who underwent surgical cricothyroidotomy. Blast injury was the predominant mechanism of injury. Major head, face and neck injuries were recorded in 83% of patients. Cricothyroidotomy was successful in 28 cases (82%), with reasons for failure recorded as bronchial intubation ($n = 1$); subcutaneous passage ($n = 1$); and unsuccessful attempt ($n = 4$).

Ultrasound guidance can be used to help identify the cricothyroid membrane [60], with Wong et al. showing this can be achieved quickly and reliably with and without a rigid neck collar [61].

There is a paucity of other evidence specifically in patients with cervical spine injury, but the same general principles apply to for all patients requiring emergency front-of-neck airway: securing the airway is a priority. The Difficult Airway Society (DAS) currently recommends the use of surgical cricothyroidotomy and, in the setting of cervical spine injury, this may also be appropriate.

- **Emergency front-of-neck airway access should be obtained in line with the Difficult Airway Society guidelines (Grade D; weak recommendation).**
- **If a patient is considered to be at risk of failed tracheal intubation, ultrasound guidance may be used to identify and mark the cricothyroid membrane before induction of anaesthesia, if resources and skill mix are appropriate. This may be done with a cervical collar in situ (Grade C; weak recommendation).**

Awake tracheal intubation

Awake tracheal intubation was historically considered by many to be the gold standard technique in patients with suspected or confirmed cervical spine injury. This was due to the perception that peri-procedural spinal cord impingement was less likely in an awake patient and allowed clinicians to demonstrate preserved neurological status after tracheal intubation, prior to induction of anaesthesia. There is, however, a paucity of data to support these hypothesised benefits.

Awake tracheal intubation using a flexible bronchoscope has been utilised less frequently since the widespread adoption of videolaryngoscopy. One single-centre retrospective study of 252 patients found that only 2.3% had ATI using a flexible bronchoscope, with 50% of the cohort having tracheal intubation using videolaryngoscopy [8]. Success rates were high for videolaryngoscopy and ATI with flexible bronchoscope (98.4% and 100% first-pass success rates, respectively) but lower for the flexible bronchoscope in patients who were anaesthetised (88.3%). No patients had a neurological deterioration related to tracheal intubation.

Dutta et al. compared cervical spine movement (using lateral fluoroscopy) during ATI using a flexible bronchoscope with the McGrath videolaryngoscope (Medtronic) [62]. Forty-six patients with unstable cervical spines were studied. Cervical spine motion during tracheal intubation was less during ATI with a flexible bronchoscope at C1/C2 but not at C3. No patients suffered any neurological complications and SAC was not measured. Success rates were similar for both techniques.

Schoettker et al. compared changes in somatosensory evoked potentials (SSEPs) during asleep tracheal intubation using an AirTraq videolaryngoscope with a flexible bronchoscope [63]. Forty patients with unstable cervical spines after trauma were studied; a cervical collar was in place during tracheal intubation. One patient in each group had alterations on SSEPs during tracheal intubation but neither had any postoperative neurological deterioration. In contrast, 13 patients had alterations in SSEPs during positioning for surgery. First pass success rate was greater in patients allocated to the AirTraq group (95% vs. 85%), although the tracheas of all patients were successfully intubated.

Jadhav et al. compared ATI via an LMA Fastrach with ATI using a flexible bronchoscope in patients having corrective surgery for cervical spine disease [64]. Assessment of cervical spine movement was done using lateral radiographs (SAC not measured) and was similar for both techniques at C1/2 and C2/3.

Malcharek et al. compared two methods of flexible bronchoscope-assisted tracheal intubation in 80 patients who had no cervical spine pathology [33]. They found that using an Aintree intubation catheter had a higher tracheal intubation success rate compared with the LMA Fastrach technique. However, no assessment of cervical spine movement was made, meaning it is impossible to extrapolate the findings to patients with cervical spine injury.

A systematic review from 2019 did not identify any studies that had compared tracheal intubation techniques done awake vs. general anaesthesia [5]. This review suggested that the overall neurological complication rate after tracheal intubation was 0.34% (4/1177 patients). However, this was only identified in three of the patients at one-week follow-up.

Overall, there is a lack of evidence to demonstrate that ATI is superior to techniques performed under general anaesthesia in terms of prevention of secondary spinal cord injury. Similarly, that is a lack of evidence to support flexible bronchoscope-guided tracheal intubation being superior to other techniques.

- **The decision to choose awake vs. a anaesthetised tracheal intubation and/or to use a flexible bronchoscope should be made on a case-by-case basis, considering patient factors, equipment availability and the proficiency of the clinician with the technique (Grade D; weak recommendation).**

Cervical spine immobilisation

A recent review called into question the routine use of MILS during tracheal intubation [65]. The review noted that although MILS has been shown to reduce cervical vertebral movement in uninjured volunteers, there are conflicting results in the presence of a cervical spine injury. Cadaveric models with surgically induced injuries have shown MILS to be ineffective in preventing cervical vertebral movement [66, 67] and may increase subluxation at the level of injury [68]. This is an important consideration, given that MILS and other methods of cervical immobilisation increase the incidence of difficult and failed tracheal intubation [41, 69–71]. These findings have been confirmed in more recent work. The use of MILS in conjunction with tracheal intubation using a Macintosh blade increased failure rates and worsened glottic views [72].

A systematic review and meta-analysis compared the effectiveness of different tracheal intubation devices in the presence of cervical spinal immobilisation [52]. It is important to note that effect of the devices on cervical spine movement and the incidence of secondary neurological injury were not assessed. In addition, only one study involved the emergency tracheal intubation of patients with acute traumatic injuries. Manual in-line stabilisation was used in 48 studies. In the presence of MILS, most videolaryngoscopes ranked above the Macintosh blade in terms of chance of first-pass success, but credibility intervals were wide. The Airway Scope (Pentax, Tokyo, Japan) ranked highest, but the authors raised concerns regarding the effect of publication bias in relation to this finding.

The presence of rigid/semi-rigid collars during tracheal intubation is associated with an increased incidence of difficult tracheal intubation, primarily due to a reduction in mouth opening [69, 73]. There is very limited, low-quality evidence supporting the efficacy of cervical collars with regards to limitation of cervical spinal movement, and no evidence of improved outcomes in terms of neurological injury or mortality [74]. In addition, in a cadaveric model of cervical instability, application of a cervical collar caused a greater degree of cervical spine movement (in terms of anterior–posterior subluxation) compared with MILS during oral tracheal intubation using direct laryngoscopy [75].

- **Manual in-line stabilisation worsens glottic view, and there is very limited evidence suggesting that it reduces the risk of secondary spinal cord injury. If clinicians choose to use MILS, then clinicians should have a low threshold for its removal in the event of difficult tracheal intubation (Grade D; weak recommendation).**
- **During tracheal intubation attempts, a semi-rigid or rigid cervical collar should be removed, which can be done most easily by only removing the anterior part of the collar; this will also help minimise any movement to the cervical spine (Grade D, weak recommendation).**

Special circumstances

Pre-hospital

We found no randomised clinical trials examining the efficacy or safety of airway management in patients with suspected or confirmed cervical spine injury in the pre-hospital setting. These environments are more challenging than in hospital, and airway management is associated with lower tracheal intubation success rates [59, 76]. Observational data show that tracheal intubation is more likely to fail in the presence of neck immobilisation (odds ratio 2.53 (95%CI 1.72–3.67)) [77]. However, we were unable to find robust evidence to reliably guide effective or safe decision-making in pre-hospital airway management with suspected or confirmed cervical spine injury.

- **Given the limited data in this setting, airway management should follow standard algorithms relevant to this particular clinical setting (Grade D; weak recommendation).**

Military

In the prehospital combat setting, cervical spine injury rarely occurs in isolation [76, 78]. Securing the airway takes priority, and tracheal intubation is viewed as the standard of care [79]. However, we were unable to find evidence demonstrating efficacy or safety of airway management in this environment.

- **Given the limited data in this setting, airway management should follow standard algorithms relevant to this particular clinical setting (Grade D; weak recommendation).**

Human factors

Airway management in the setting of cervical spine injury is associated with increased risk, and therefore careful planning, preparation, and optimisation of human factors may improve patient outcomes [80]. Patients in whom cervical spine injury is suspected or confirmed often require tracheal intubation outside the operating theatre (e.g. in the emergency department), which is associated with additional non-procedural challenges relating to situation (e.g. limited space and poor lighting), logistics (e.g. equipment availability) and operator (e.g. increased stress and risk of cognitive overload) [81].

Although we found no specific high or intermediate-quality data relating to human factors in this setting, many generic human factors principles may be of value including: the use of cognitive aids and checklists; strategies to maintain situational awareness in the peri-intubation period; decision-making processes/sequences (e.g. T-DODAR) to help determine the best tracheal intubation technique for a particular patient; and techniques to improve task management and team performance.

- **Multidisciplinary planning, preparation and optimisation of human factors should be considered before airway management in patients with suspected or confirmed cervical spine injury (Grade D; weak recommendation).**

Discussion

These recommendations have been made using the best available evidence and pragmatic expert consensus. Given the need for guidance in this area, we have aimed to support clinicians to use the most appropriate tools available to them and suitable for a given situation. However, we recognise that the evidence base upon which many of our recommendations are made is modest. There is an opportunity for future research across all areas of airway management in the setting of suspected or confirmed cervical spine injury. For example, research is needed to determine the utility of `steerable´ or flexible-tipped bougies and the requirements for adjuncts with different types of videolaryngoscopes (e.g. hyperangulated vs. Macintosh-style blade). Moreover, the precise choice of different devices remains unclear, such as different supraglottic airway designs or videolaryngoscope blades. The magnitude of any potential impact of ATI on cervical spine movement needs to be better understood. Importantly, there is very little contemporary evidence that any airway manoeuvre or procedure has been explicitly associated with adverse spinal cord outcomes – which is very difficult to prospectively study – but most data infer risk based on the surrogate of head and neck movement.

There are limitations to this guideline. As noted, the level of evidence and strength of recommendations are modest, and therefore consensus recommendations were required. We synthesised data qualitatively and did not perform any statistical analyses. Some recommendations may be aspirational, and others lean on guidance produced by others.

In summary, we produced multidisciplinary, multisociety guidelines aiming to improve safety in airway management in patients with suspected or confirmed cervical spine injury. We hope the pragmatic approach to airway management will improve patient care.

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Supporting Information

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

Figure S1. PRISMA flow diagram.

Table S1. Grading of recommendations based on the level of evidence available.

Appendix S1. Risk of bias assessment for included randomised controlled trials clinical studies.

Appendix S2. Risk of bias assessment for included randomised crossover trials clinical studies.

Appendix S3. Newcastle–Ottawa scores for included observational studies.

Appendix S4. Results from included studies.

Appendix S5. Full Delphi process results.