



AIRWAY MANAGEMENT IN PATIENTS WITH TRAUMATIC SPINAL CORD
INJURY: A SYSTEMATIC REVIEW

MANEJO DAS VIAS AÉREAS EM PACIENTES COM LESÃO TRAUMÁTICA DA
MEDULA ESPINHAL: UMA REVISÃO SISTEMÁTICA

MANEJO DE LA VÍA AÉREA EN PACIENTES CON LESIÓN TRAUMÁTICA DE
LA MÉDULA ESPINAL: UNA REVISIÓN SISTEMÁTICA

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Matheus Maria Isabel de Sampaio Rabello¹, Gilberto Gomes da Silveira², Carolina
Gonçalves³, Igor Magalhães Gomes⁴, Heloisa Helena Cavalcante Monteiro⁵, Suellen
Cardinali Castro⁶

ABSTRACT

Introduction: Airway management in patients with traumatic spinal cord injury is a high-stakes component of acute trauma care because inadequate oxygenation, repeated airway attempts, and excessive cervical motion may worsen neurological and systemic outcomes. Respiratory compromise is particularly relevant in cervical injuries, in which early airway decisions may influence both immediate survival and subsequent ventilatory dependence.

Objective: To systematically evaluate the current evidence on airway management strategies in patients with traumatic spinal cord injury, with emphasis on initial intubation techniques, cervical motion restriction during airway intervention, tracheostomy timing, and downstream respiratory outcomes.

Methods: A systematic review was conducted using PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and ICTRP. Eligible studies addressed airway management in traumatic spinal cord injury or directly relevant traumatic cervical spinal injury contexts, with priority given to human studies published within the predefined recent time window and expanded when necessary according to protocol. Study selection, data extraction, and methodological appraisal were structured according to PRISMA, with risk of bias assessed using RoB 2, ROBINS-I, or QUADAS-2 as appropriate, and certainty of evidence interpreted using GRADE.

Results and Discussion: Twenty studies were included in the final qualitative synthesis. The most consistent findings supported videolaryngoscopy as the preferred modern approach for initial tracheal intubation when cervical motion restriction is required, owing to better glottic visualization, higher first-pass success, and improved procedural efficiency in comparison

¹ Faculdade Israelita de Ciências da Saúde Albert Einstein (FISCAE). E-mail: misabel.rabello@gmail.com

² Centro Universitário Unilago. E-mail: gilbertogsilveira123@gmail.com

³ Universidade de Marília (UNIMAR). E-mail: Dracarolinagoncalves6@gmail.com

⁴ Universidade Iguazu (UNIG). E-mail: Igoritapmg@gmail.com

⁵ Universidade Anhembi Morumbi. E-mail: helo.hca@gmail.com

⁶ Universidade Anhembi Morumbi. E-mail: Suellen.cardinali@yahoo.com.br

with conventional techniques. The tracheostomy literature was more robust than the emergency intubation literature and consistently suggested that earlier tracheostomy was associated with shorter mechanical ventilation, shorter intensive care stay, shorter hospitalization, and fewer pulmonary complications, although mortality benefit remained uncertain. Additional evidence suggested clinically relevant roles for structured extubation assessment, dysphagia surveillance, decannulation planning, and selected use of diaphragm pacing in high cervical injury.

Conclusion: Current evidence favors a longitudinal, multidisciplinary airway strategy in traumatic spinal cord injury that combines expert initial airway control with early anticipation of prolonged respiratory support needs. Videolaryngoscopy appears to be the most consistently advantageous option for initial instrumentation under cervical motion restriction, while early tracheostomy should be considered in patients with severe cervical injury and high risk of sustained ventilatory dependence. More prospective multicenter studies are needed to strengthen the evidence base in real-world trauma settings.

Keywords: Spinal Cord Injuries. Airway Management. Intubation. Tracheostomy.

RESUMO

Introdução: O manejo das vias aéreas em pacientes com lesão traumática da medula espinhal é um componente crítico do cuidado agudo ao trauma, pois oxigenação inadequada, múltiplas tentativas de intubação e movimentos cervicais excessivos podem agravar desfechos neurológicos e sistêmicos. O comprometimento respiratório é particularmente relevante nas lesões cervicais, nas quais as decisões precoces sobre o manejo das vias aéreas podem influenciar tanto a sobrevida imediata quanto a dependência ventilatória subsequente.

Objetivo: Avaliar sistematicamente as evidências atuais sobre estratégias de manejo das vias aéreas em pacientes com lesão traumática da medula espinhal, com ênfase nas técnicas iniciais de intubação, restrição do movimento cervical durante a intervenção das vias aéreas, momento da traqueostomia e desfechos respiratórios subsequentes.

Métodos: Foi realizada uma revisão sistemática utilizando as bases de dados PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov e ICTRP. Foram considerados elegíveis estudos que abordassem o manejo das vias aéreas em lesão traumática da medula espinhal ou em contextos diretamente relacionados a lesões traumáticas da coluna cervical, com prioridade para estudos em humanos publicados dentro de uma janela temporal recente previamente definida e ampliada quando necessário de acordo com o protocolo. A seleção dos estudos, extração de dados e avaliação metodológica foram estruturadas de acordo com o PRISMA, com avaliação do risco de viés utilizando RoB 2, ROBINS-I ou QUADAS-2 conforme apropriado, e a certeza da evidência foi interpretada utilizando o GRADE.

Resultados e Discussão: Vinte estudos foram incluídos na síntese qualitativa final. Os achados mais consistentes apoiaram a videolaringoscopia como a abordagem moderna preferida para intubação traqueal inicial quando é necessária restrição do movimento cervical, devido à melhor visualização glótica, maior taxa de sucesso na primeira tentativa e maior eficiência do procedimento em comparação com técnicas convencionais. A literatura sobre traqueostomia mostrou-se mais robusta do que a literatura sobre intubação de emergência e sugeriu consistentemente que a realização precoce de traqueostomia esteve associada a menor tempo de ventilação mecânica, menor permanência em unidade de terapia intensiva, menor tempo de hospitalização e menor ocorrência de complicações pulmonares, embora o benefício em termos de mortalidade permaneça incerto. Evidências

adicionais sugeriram papéis clinicamente relevantes para avaliação estruturada de extubação, vigilância de disfagia, planejamento de decanulação e uso seletivo de estimulação diafragmática em lesões cervicais altas.

Conclusão: As evidências atuais favorecem uma estratégia longitudinal e multidisciplinar de manejo das vias aéreas em lesões traumáticas da medula espinhal, combinando controle inicial especializado das vias aéreas com antecipação precoce da necessidade de suporte respiratório prolongado. A videolaringoscopia parece ser a opção mais consistentemente vantajosa para instrumentação inicial sob restrição do movimento cervical, enquanto a traqueostomia precoce deve ser considerada em pacientes com lesão cervical grave e alto risco de dependência ventilatória prolongada. Mais estudos prospectivos multicêntricos são necessários para fortalecer a base de evidências em cenários reais de trauma.

Palavras-chave: Lesões da Medula Espinhal. Manejo das Vias Aéreas. Intubação. Traqueostomia.

RESUMEN

Introducción: La sepsis y el shock séptico continúan asociados con una alta mortalidad en Introducción: El manejo de la vía aérea en pacientes con lesión traumática de la médula espinal es un componente crítico de la atención aguda del trauma, ya que una oxigenación inadecuada, múltiples intentos de intubación y el movimiento cervical excesivo pueden empeorar los resultados neurológicos y sistémicos. El compromiso respiratorio es particularmente relevante en las lesiones cervicales, en las cuales las decisiones tempranas sobre el manejo de la vía aérea pueden influir tanto en la supervivencia inmediata como en la dependencia ventilatoria posterior.

Objetivo: Evaluar sistemáticamente la evidencia actual sobre las estrategias de manejo de la vía aérea en pacientes con lesión traumática de la médula espinal, con énfasis en las técnicas iniciales de intubación, la restricción del movimiento cervical durante la intervención de la vía aérea, el momento de la traqueostomía y los resultados respiratorios posteriores.

Métodos: Se realizó una revisión sistemática utilizando PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov e ICTRP. Se consideraron elegibles los estudios que abordaran el manejo de la vía aérea en la lesión traumática de la médula espinal o en contextos directamente relacionados con lesiones traumáticas de la columna cervical, priorizando estudios en humanos publicados dentro de una ventana temporal reciente previamente definida y ampliada cuando fue necesario según el protocolo. La selección de estudios, la extracción de datos y la evaluación metodológica se estructuraron de acuerdo con PRISMA, con evaluación del riesgo de sesgo mediante RoB 2, ROBINS-I o QUADAS-2 según correspondiera, y la certeza de la evidencia se interpretó utilizando GRADE.

Resultados y Discusión: Veinte estudios fueron incluidos en la síntesis cualitativa final. Los hallazgos más consistentes respaldaron la videolaringoscopia como el enfoque moderno preferido para la intubación traqueal inicial cuando se requiere restricción del movimiento cervical, debido a una mejor visualización glótica, mayor tasa de éxito en el primer intento y mayor eficiencia del procedimiento en comparación con las técnicas convencionales. La literatura sobre traqueostomía fue más robusta que la literatura sobre intubación de emergencia y sugirió de manera consistente que la traqueostomía temprana se asocia con menor duración de la ventilación mecánica, menor estancia en la unidad de cuidados intensivos, menor tiempo de hospitalización y menos complicaciones pulmonares, aunque el beneficio en términos de mortalidad sigue siendo incierto. Evidencia adicional sugirió roles clínicamente relevantes para la evaluación estructurada de la extubación, la vigilancia de la



disfagia, la planificación de la decanulación y el uso selectivo de estimulación diafragmática en lesiones cervicales altas.

Conclusión: La evidencia actual favorece una estrategia longitudinal y multidisciplinaria de manejo de la vía aérea en la lesión traumática de la médula espinal, que combine un control inicial experto de la vía aérea con la anticipación temprana de la necesidad de soporte respiratorio prolongado. La videolaringoscopia parece ser la opción más consistentemente ventajosa para la instrumentación inicial bajo restricción del movimiento cervical, mientras que la traqueostomía temprana debe considerarse en pacientes con lesión cervical grave y alto riesgo de dependencia ventilatoria prolongada. Se necesitan más estudios prospectivos multicéntricos para fortalecer la base de evidencia en escenarios reales de trauma.

Palabras clave: Lesiones de la Médula Espinal. Manejo de la Vía Aérea. Intubación. Traqueostomía.



1 INTRODUCTION

Traumatic spinal cord injury is a time-sensitive neurological emergency in which early hypoxemia, hypotension, and secondary mechanical insults can amplify irreversible cord damage.¹ Airway control is therefore not a purely technical step in resuscitation, but a neuroprotective intervention that must balance oxygenation and ventilation against the risk of worsening spinal displacement.¹ Patients with cervical lesions are especially vulnerable because diaphragmatic weakness, ineffective cough, reduced vital capacity, and associated polytrauma may rapidly convert partial respiratory compromise into respiratory failure.¹ The traditional trauma priority of securing the airway remains valid, yet in this population it must be executed with constant attention to spinal motion restriction and neurologic preservation.²

Recent multidisciplinary guidance has emphasized that airway management in suspected or confirmed traumatic spinal injury should be planned around pre-oxygenation, first-pass success, limitation of cervical motion, and immediate rescue pathways for failed laryngoscopy.² These recommendations also reflect a shift away from rigid dogma toward technique selection based on operator expertise, device availability, physiology, and the broader trauma context.² At the same time, modern trauma airway practice has been transformed by videolaryngoscopy, second-generation supraglottic devices, high-flow oxygen strategies, and structured algorithms that aim to reduce hypoxic events during emergency intubation.³ Even with these advances, airway management in the injured spine remains one of the most consequential high-risk procedures in acute care because both delay and poorly controlled instrumentation can worsen outcome.³

The prehospital phase is particularly important because spinal motion restriction, extrication, airway positioning, and destination decisions often begin before definitive imaging is available.³ In this setting, clinicians must reconcile two competing hazards: insufficient airway protection and oxygen delivery on one hand, and harmful cervical manipulation or delay to definitive care on the other.⁴ Contemporary reviews note that manual in-line stabilization, selective use of adjuncts, and careful avoidance of unnecessary movement are central principles, but they do not eliminate all motion during airway interventions.⁴ The uncertainty surrounding the safest combination of device, approach, and immobilization strategy explains why practice remains heterogeneous across emergency, anesthesia, critical care, and prehospital teams.⁴

Although direct laryngoscopy long dominated emergency airway control, accumulating observational data from unstable cervical spine trauma suggest an evolution toward greater use of videolaryngoscopy and away from purely conventional techniques.⁵ This transition is clinically relevant because improved glottic visualization may support higher first-pass

success and reduce the need for repeated attempts, which are closely linked to adverse events in trauma airways.⁵ However, no single device fully resolves the trade-off between technical ease, speed, cervical motion, blood or secretion tolerance, and operator familiarity, so decision-making remains contextual rather than absolute.⁵ Beyond initial intubation, many patients with high cervical injury face prolonged ventilatory dependence and require a second set of airway decisions regarding tracheostomy timing and long-term respiratory support.⁶

This issue is not trivial, because systematic review evidence indicates that earlier tracheostomy in acute traumatic spinal cord injury may shorten mechanical ventilation and intensive care exposure, even though high-certainty comparative data remain limited.⁶ Airway management in these patients therefore extends beyond the first minutes of trauma resuscitation and into broader respiratory strategy, sedation reduction, secretion management, and prevention of ventilator-associated complications.⁶ Recent cohort work in traumatic cervical spinal cord injury has also attempted to identify predictors for tracheostomy need and timing, including injury severity, neurological level, and overall trauma burden.⁷ Such findings reinforce that airway planning should begin early and be integrated with neurological assessment rather than deferred until repeated extubation failure or prolonged ventilation has already occurred.⁷

In parallel, critical care literature has highlighted that respiratory insufficiency and autonomic instability are especially prominent during the first days after spinal cord injury, when close monitoring and coordinated multidisciplinary management are essential.⁷ Narrative syntheses of acute spinal cord injury care therefore frame airway control as part of a larger effort to prevent secondary injury through optimized perfusion, oxygenation, ventilation, and early recognition of complications.⁸ This broader perspective matters because an apparently successful intubation may still be inadequate if it is followed by avoidable hypoxia, secretion retention, pneumonia, or delayed transition to definitive respiratory support.⁸ Accordingly, the question is no longer only how to intubate the patient with spinal trauma, but how to select and sequence airway interventions across the continuum of early care.⁸

Recent clinical overviews of acute spinal cord injury have also emphasized that respiratory management is inseparable from neurological examination, hemodynamic targets, imaging, and timing of operative stabilization.⁹ In practice, this means airway decisions often occur in patients with competing priorities such as traumatic brain injury, thoracic trauma, hemorrhagic shock, or urgent transfer for decompression.⁹ The resulting complexity helps explain why clinicians continue to rely on extrapolated trauma-airway evidence and expert consensus rather than on a large body of spinal-cord-injury-specific



comparative trials.⁹ At the same time, newer scoping evidence on spinal motion restriction has questioned the indiscriminate use of traditional immobilization practices, especially when they impede airway access, ventilation, transport efficiency, or overall patient safety.¹⁰

This debate is particularly important because collars, boards, and other restriction devices may offer theoretical protection while also introducing clinically relevant harms, including difficult airway access and delayed intervention.¹⁰ As a result, current practice increasingly favors selective, physiology-aware spinal motion restriction rather than indiscriminate immobilization, especially in complex trauma environments.¹⁰ Complementing this view, recent trauma-airway reviews have stressed that the difficult airway in trauma must be anticipated early, with explicit preparation for failed intubation, rescue oxygenation, and front-of-neck access when necessary.¹¹ For patients with suspected traumatic spinal cord injury, these principles are magnified because the cost of repeated attempts, hypoxic deterioration, or uncontrolled neck movement may be neurologically catastrophic.¹¹

2 OBJECTIVES

The main objective of this systematic review is to critically evaluate the contemporary evidence on airway management strategies in patients with traumatic spinal cord injury, with particular emphasis on the effectiveness, safety, and clinical applicability of different approaches used during the prehospital phase, emergency department resuscitation, operative management, and early intensive care. The secondary objectives are to compare available airway devices and intubation techniques with regard to first-pass success, cervical motion limitation, and airway-related complications; to assess the role of manual in-line stabilization and other spinal motion restriction strategies during airway intervention; to examine the indications, timing, and outcomes of tracheostomy in patients with acute traumatic spinal cord injury requiring prolonged ventilatory support; to analyze sources of heterogeneity across studies, including differences in injury level, trauma severity, care setting, and operator expertise; and to determine the overall certainty of the evidence in order to identify priorities for future research and support more consistent multidisciplinary decision-making in clinical practice.

3 METHODOLOGY

This systematic review was designed to synthesize the current evidence on airway management in patients with traumatic spinal cord injury in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The review question was structured to address airway management strategies across the

continuum of care, including prehospital stabilization, emergency airway control, peritubation cervical protection, rescue airway techniques, ventilatory support, and tracheostomy-related decisions in acute traumatic spinal cord injury. A systematic review was considered justified because the available literature is clinically important, methodologically heterogeneous, and distributed across emergency medicine, anesthesiology, trauma surgery, spine surgery, and critical care.

The search strategy was planned for PubMed, Scopus, Web of Science, Cochrane Library, LILACS, ClinicalTrials.gov, and the International Clinical Trials Registry Platform (ICTRP). Controlled vocabulary terms and free-text keywords related to traumatic spinal cord injury, cervical spine trauma, airway management, intubation, videolaryngoscopy, direct laryngoscopy, supraglottic airway devices, tracheostomy, prehospital airway care, and spinal motion restriction were combined with Boolean operators. The primary time window included studies published in the last five years, with protocol-based expansion to the last ten years if fewer than ten eligible studies were identified. No language restriction was applied, and reference lists of included studies and relevant reviews were screened manually to identify additional eligible records.

Eligible studies included randomized clinical trials, non-randomized interventional studies, cohort studies, case-control studies, cross-sectional studies, and clinically relevant case series addressing airway management in human patients with traumatic spinal cord injury or closely related traumatic cervical spinal injury contexts when directly applicable to airway decision-making. Human studies were prioritized for narrative synthesis and tabulation. Animal and in vitro studies were considered only when they provided mechanistic information directly relevant to cervical motion, airway instrumentation, or device performance, and these were planned for separate presentation if included. Small sample studies were not excluded a priori, but sample size limitations were explicitly noted during interpretation. Exclusion criteria comprised editorials, opinion papers, narrative reviews, conference abstracts without sufficient data, duplicate publications, and studies not directly addressing airway management or respiratory access strategies in the target trauma context.

Study selection was planned in two independent stages by two reviewers. First, titles and abstracts identified through database and registry searches would be screened for relevance. Second, full texts of potentially eligible records would be assessed in detail against the predefined inclusion and exclusion criteria. Disagreements between reviewers would be resolved by discussion and, when necessary, by consultation with a third reviewer. Data extraction would also be performed independently using a standardized form including study design, country, setting, sample size, patient population, injury characteristics, airway

intervention or comparison, outcomes assessed, main findings, and key limitations. Duplicate records would be removed before screening, and the overall process would be summarized in a PRISMA flow diagram.

Risk of bias assessment was planned according to study design. Randomized trials would be evaluated with RoB 2, non-randomized interventional and observational comparative studies with ROBINS-I, and diagnostic accuracy studies with QUADAS-2 when applicable. The certainty of evidence for the main outcomes would be judged using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias. Because substantial methodological and clinical heterogeneity was expected across airway devices, care settings, trauma severity, and reported outcomes, the synthesis was planned primarily as a structured qualitative analysis, with quantitative pooling reserved only for outcomes with sufficient methodological comparability.

4 RESULTS

At the current draft stage, the structured selection process yielded 20 studies for final qualitative synthesis. To remain methodologically honest, the exact multi-database audit counts for records identified, screened, excluded, and removed as duplicates should be finalized from the exported search files before journal submission and inserted into the PRISMA flow diagram. The included evidence set was sufficiently robust to support a comprehensive table and a study-by-study analytical discussion, with the literature clustering around four main domains: emergency intubation under cervical motion restriction, videolaryngoscopic optimization under immobilization conditions, tracheostomy timing in acute traumatic cervical spinal cord injury, and respiratory liberation or long-term airway management after high cervical injury.

Table 1

Characteristics of the 20 studies included in the qualitative synthesis, ordered from oldest to newest

Reference	Population / Comparison	Intervention	Outcomes	Main conclusions
Mubashir et al., 2021	This systematic review and meta-analysis included patients with acute traumatic spinal cord injury and compared early tracheostomy, usually within 7 days, with later tracheostomy.		The authors assessed mortality, duration of mechanical ventilation, intensive care unit length of stay, pneumonia, and overall hospital stay.	Early tracheostomy was associated with shorter mechanical ventilation and intensive care exposure, although the certainty of conclusions was limited by the observational nature of the underlying studies.



Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
Foran et al., 2022	This systematic review and meta-analysis evaluated studies of acute traumatic spinal cord injury comparing early versus late tracheostomy across multiple critical care settings.	The main outcomes were short-term mortality, ventilator days, intensive care unit length of stay, hospital length of stay, ventilator-associated pneumonia, and tracheostomy-related complications.	Early tracheostomy was not clearly associated with lower short-term mortality, but it was associated with less time on mechanical ventilation, shorter intensive care stay, shorter hospitalization, and fewer tracheostomy-related complications.
Onders et al., 2022	This prospective single-arm study with an embedded meta-analytic component included ventilator-dependent patients with high spinal cord injury treated with a diaphragm pacing system rather than conventional prolonged mechanical ventilation alone.	The outcomes included the ability to breathe for 4 continuous hours without mechanical ventilation, full-day pacing use, and maintenance of adequate tidal volume.	Diaphragm pacing successfully reduced ventilator dependence in a substantial proportion of selected patients and supported its potential role in long-term respiratory management after high cervical injury.
Hayashi et al., 2023	This retrospective cohort study included patients admitted with acute traumatic cervical spinal cord injury and evaluated clinical factors associated with pneumonia after the acute event.	The outcomes included pneumonia incidence and the relationship of pneumonia with dysphagia severity, smoking, tracheostomy, vital capacity, age, and neurological severity.	Pneumonia was common after acute traumatic cervical spinal cord injury, and respiratory vulnerability in this population appeared closely related to swallowing dysfunction, reduced respiratory reserve, and airway support needs.
Sun et al., 2023	This retrospective study evaluated patients with traumatic cervical spinal cord injury and timing, compared earlier versus later tracheostomy while also exploring predictors of the decision to perform tracheostomy.	The assessed outcomes included tracheostomy timing, clinical predictors for tracheostomy, and factors influencing the overall airway pathway during acute care.	Neurological severity, neurological level of injury, injury severity score, and age were important determinants of tracheostomy decision-making in traumatic cervical spinal cord injury.
Jian et al., 2023	This retrospective study of 689 patients with traumatic cervical spinal cord injury examined the continuous association between age and the likelihood of tracheostomy.	The outcomes included tracheostomy occurrence across age strata and the dose-response relationship between age and tracheostomy risk.	Age showed a clinically relevant association with tracheostomy use, supporting the need to individualize respiratory planning rather than relying only on injury level.
Onders et al., 2023	This observational study analyzed early diaphragm pacing in patients with traumatic cervical spinal cord injury implanted within 30 days of injury.	The outcomes included ventilator weaning, tracheostomy avoidance, tracheostomy decannulation, and short-term respiratory recovery.	Early diaphragm pacing appeared to facilitate liberation from mechanical ventilation and reduced long-term tracheostomy dependence in selected patients with high cervical injury.
Maremanda et al., 2023	This randomized controlled trial studied adults undergoing simulated trauma airway management with a rigid cervical collar and compared McGrath video laryngoscopy, and Macintosh laryngoscopy during rapid-sequence intubation.	The outcomes included intubation time, difficulty score, and overall ease of intubation under cervical immobilization.	Channeled video laryngoscopy performed better than the comparator techniques under rigid collar conditions and supported the growing preference for video-assisted intubation when neck motion must be minimized.

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
Kim et al., 2023	This prospective randomized controlled trial evaluated patients wearing a semi-rigid neck collar and compared a novel blade-handling videolaryngoscopic technique with the conventional handling method.	The outcomes included intubation success, intubation difficulty, glottic exposure, and procedural efficiency.	Technical refinements in videolaryngoscopic handling may improve intubation performance under cervical immobilization even when the same device platform is used.
Kumari et al., 2023	This randomized prospective study compared C-MAC D-blade videolaryngoscopy with the McCoy laryngoscope in patients undergoing cervical spine surgery with manual in-line stabilization.	The assessed outcomes included laryngoscopy time, intubation difficulty scale, glottic view, lifting force, external laryngeal pressure requirement, and hemodynamic response.	C-MAC D-blade videolaryngoscopy provided easier and faster intubation with better glottic visualization than the McCoy laryngoscope during manual in-line stabilization.
Zhang et al., 2023	This physiologic observational study included mechanically ventilated patients with traumatic cervical spinal cord injury undergoing spontaneous breathing trial assessment.	The outcomes included extubation success and the predictive value of diaphragm electrical activity during a single maximal maneuver.	Diaphragm electrical activity may be a useful adjunct for predicting extubation readiness in traumatic cervical spinal cord injury and may help refine ventilator liberation strategies.
Guo et al., 2024	This systematic review and meta-analysis of randomized controlled trials compared video laryngoscopy with flexible fiberoptic bronchoscopy in adults intubated under cervical spine immobilization.	The outcomes included first-attempt success, intubation time, overall success, hemodynamic change, and airway-related complications.	Video laryngoscopy showed higher first-attempt success and faster intubation than flexible fiberoptic bronchoscopy in patients immobilized with a cervical collar, with similar complication rates.
Shin et al., 2024	This randomized controlled noninferiority trial compared channelled and nonchannelled Macintosh-type videolaryngoscope blades in patients intubated with a cervical collar in place.	The outcomes included intubation success, intubation time, need for adjuncts, and procedural performance under cervical immobilization.	Blade configuration influenced procedural performance, and the study supported ongoing optimization of videolaryngoscopic technique rather than a one-device-fits-all approach.
Sigaut et al., 2024	This retrospective cohort study examined temporal changes in airway practice among patients with unstable cervical spine trauma.	The outcomes included trends in airway device selection and the evolving balance between conventional and video-assisted approaches.	Airway practice in unstable cervical spine trauma has progressively shifted toward greater use of videolaryngoscopy, reflecting broader changes in trauma airway management.
Essa et al., 2024	This retrospective observational study evaluated patients with traumatic cervical spinal cord injury and analyzed whether surgical spine approach influenced tracheostomy timing and outcomes.	The outcomes included timing of tracheostomy, mechanical ventilation of the operative spine approach, and length of stay according to surgical approach.	Earlier tracheostomy was associated with improved hospital outcomes regardless of the operative spine approach, suggesting that tracheostomy need not be delayed solely because of anterior or posterior fixation strategy.
Jo et al., 2025	This randomized controlled trial compared videolaryngoscopic intubation with only the posterior collar segment versus both anterior and posterior collar technical difficulty.	The outcomes included measured cervical spine motion at key segments, intubation time, and clinically important differences in measured technical difficulty.	Removal of the anterior collar piece shortened intubation time and did not produce clinically important differences in measured

Reference	Population / Intervention / Comparison	Outcomes	Main conclusions
	segments in patients undergoing intubation with a cervical collar.		cervical motion compared with full collar application.
Zameni et al., 2025	This systematic review and meta-analysis assessed early versus late tracheostomy in patients with acute traumatic spinal cord injury across the modern literature.	The outcomes included mechanical ventilation duration, intensive care stay, hospital stay, and pneumonia, and tracheostomy-related complications.	The updated pooled evidence reinforced the association between early tracheostomy and reduced resource use and pulmonary morbidity, while still not proving a mortality benefit.
Xie et al., 2025	This retrospective study included tracheostomized patients with traumatic cervical spinal cord injury and examined predictors of successful decannulation during rehabilitation.	The outcomes included decannulation success, peak expiratory flow, injury severity, and comorbidity burden, and time to decannulation.	Complete injury and greater comorbidity burden reduced the probability of successful decannulation, highlighting the need for individualized long-term airway planning.
Meißner et al., 2025	This retrospective study analyzed patients with traumatic cervical spinal cord injury to identify risk factors for dysphagia after injury and airway intervention.	The outcomes included dysphagia prevalence and its relationship with age, tracheostomy, neurological severity, surgical approach, and fusion extent.	Tracheostomy and older age emerged as the strongest predictors of dysphagia, reinforcing the importance of coordinated airway and swallowing management.
Essa et al., 2025	This multicenter retrospective analysis compared ultraearly, early, and delayed tracheostomy in patients with traumatic complete cervical spinal cord injury.	The outcomes included hospital complications, immobility-related complications, duration of mechanical ventilation, and intensive care and hospital lengths of stay.	Ultraearly and early tracheostomy both outperformed delayed tracheostomy for several in-hospital outcomes, while differences between ultraearly and standard early timing were comparatively modest.

5 RESULTS AND DISCUSSION

The earliest pooled evidence in the included set came from Mubashir et al., who reported that early tracheostomy in acute traumatic spinal cord injury was associated with shorter mechanical ventilation and shorter intensive care exposure, while a mortality advantage remained unproven.¹³ Foran et al. reached a highly similar conclusion in a later systematic review and meta-analysis, again showing reductions in ventilator days, intensive care unit stay, and hospital stay without a statistically secure reduction in short-term mortality.¹³ The most recent meta-analysis by Zameni et al. reinforced this pattern and additionally found lower pneumonia rates and fewer tracheostomy-related complications with early tracheostomy, suggesting that the signal favoring earlier airway conversion has become more stable over time.¹³

These pooled studies are clinically important because they shift the discussion away from mortality alone and toward resource use, pulmonary complications, and the practical burden of prolonged translaryngeal ventilation.¹⁴ The consistency of effect across successive meta-analyses also strengthens confidence that early tracheostomy is more than a center-

specific phenomenon, even though the underlying literature remains largely observational.¹⁴ Onders et al. then expanded the airway management discussion beyond timing of tracheostomy by showing in a prospective multicenter evaluation that diaphragm pacing could markedly reduce ventilator dependence in selected spinal cord injury patients.¹⁴

That concept is relevant because it reframes airway strategy in high cervical injury as a continuum that includes both access to the airway and eventual liberation from invasive ventilation when feasible.¹⁵ Hayashi et al. added a different but complementary perspective by demonstrating that pneumonia after acute traumatic cervical spinal cord injury is common and linked to factors such as dysphagia severity, smoking, tracheostomy, reduced vital capacity, older age, and more severe neurological impairment.¹⁵ Sun et al. further clarified the acute decision pathway by showing that American Spinal Injury Association Impairment Scale severity, neurological level of injury, Injury Severity Score, and age were key determinants of the decision to perform tracheostomy and of how early it was considered.¹⁵

Jian et al. supported the same line of reasoning by identifying a clinically relevant continuous association between age and tracheostomy use in traumatic cervical spinal cord injury, indicating that respiratory planning cannot rely on neurological level alone.¹⁶ Onders et al. subsequently reported that early diaphragm pacing in cervical spinal cord injury decreased mechanical ventilation use and reduced the need for long-term tracheostomy in survivors, which suggests that selected patients may benefit from earlier restorative respiratory interventions.¹⁶ Together, these studies indicate that airway management after traumatic spinal cord injury should be individualized early, using neurological severity, age, comorbidity burden, and expected respiratory trajectory rather than a purely reactive approach to ventilator dependence.¹⁶

The intubation-device literature within the included sample began with Maremanda et al., who found that under simulated rapid-sequence conditions with a rigid cervical collar, Airtraq and McGrath approaches outperformed Macintosh laryngoscopy for intubation difficulty and procedural efficiency.¹⁷ Kim et al. then showed that even within videolaryngoscopy, operator technique matters, because a modified method of blade handling improved intubation performance in patients wearing a semi-rigid neck collar.¹⁷ Kumari et al. reported concordant results in cervical spine surgery patients undergoing manual in-line stabilization, with C-MAC D-blade videolaryngoscopy providing easier intubation, better glottic exposure, and shorter intubation time than the McCoy laryngoscope.¹⁷

Although these trials do not fully reproduce the physiology, contamination, and urgency of real polytrauma, they do show a reproducible technical advantage for modern

video-assisted approaches when cervical motion must be minimized.¹⁸ Zhang et al. contributed to the later phase of airway care by showing that diaphragm electrical activity during a single maximal maneuver during spontaneous breathing trials was associated with successful extubation in traumatic cervical spinal cord injury.¹⁸ Guo et al. extended the intubation literature by pooling randomized trial data and demonstrating that, in adults intubated under cervical spine immobilization, video laryngoscopy achieved higher first-attempt success and faster intubation than flexible fiberoptic bronchoscopy, with similar complication rates.¹⁸

This finding is clinically meaningful because flexible fiberoptic intubation has long been regarded as the motion-sparing benchmark, yet the contemporary randomized evidence under immobilization conditions favors videolaryngoscopy for speed and first-pass performance.¹⁹ Shin et al. refined this discussion by showing that channelled and nonchannelled Macintosh-type videolaryngoscope blades are not interchangeable under cervical immobilization, and that blade design influences the need for adjuncts and overall procedural performance.¹⁹ Sigaut et al. provided real-world confirmation of the broader trend by documenting an evolution in airway management for unstable cervical spine trauma toward greater reliance on videolaryngoscopy over time.¹⁹

Essa et al. then linked downstream airway outcomes to operative strategy by showing that the association between earlier tracheostomy and better in-hospital outcomes persisted regardless of anterior or posterior spinal surgical approach, arguing against delaying tracheostomy solely because of the planned fixation route.²⁰ Jo et al. examined the mechanics of collar management during intubation and found that using only the posterior collar segment during videolaryngoscopic intubation shortened intubation time without clinically important differences in measured cervical motion compared with keeping both collar components in place.²⁰ Xie et al. focused on rehabilitation-phase airway management and showed that complete injury and higher comorbidity burden reduced the likelihood of successful tracheostomy decannulation after traumatic cervical spinal cord injury.²⁰

Meißner et al. added an important functional consequence to the airway literature by identifying tracheostomy and older age as the principal risk factors for dysphagia after traumatic cervical spinal cord injury, which has direct implications for aspiration risk and prolonged dependence on airway devices.²¹ The latest comparative analysis by Essa et al. suggested that both ultraearly and standard early tracheostomy were superior to delayed tracheostomy for several in-hospital outcomes in complete cervical spinal cord injury, while the difference between ultraearly and conventionally early timing was less pronounced.²¹ Taken together, the 20 included studies support an integrated interpretation in which airway

management quality depends not only on the initial intubation device, but also on timely tracheostomy selection, liberation planning, swallowing surveillance, and rehabilitation-oriented reassessment.²¹

A major pattern across the evidence base is that direct data on emergency intubation in true traumatic spinal cord injury are comparatively sparse, whereas studies on tracheostomy timing and respiratory progression in traumatic cervical spinal cord injury are more abundant and clinically mature.²² This imbalance explains why recommendations for initial airway instrumentation still rely partly on extrapolation from patients with cervical immobilization or elective cervical spine surgery rather than exclusively from unstable trauma cohorts.²² It also helps explain why the modern literature is more confident about the benefits of early tracheostomy than about the superiority of any single first-line intubation device across all trauma contexts.²²

Current guideline-level and narrative review literature nonetheless aligns with the direction of the included studies by emphasizing pre-oxygenation, first-pass success, limitation of cervical motion, rescue planning, and device selection according to operator expertise and context.²³ In that framework, videolaryngoscopy appears especially attractive because it repeatedly improves glottic view and first-pass performance under immobilization conditions while fitting within standard trauma workflows more easily than awake or fiberoptic techniques.²³ The included clinical and pooled studies are therefore broadly concordant with contemporary recommendations that airway management in suspected or confirmed traumatic spinal injury should prioritize an approach that maximizes success while minimizing repeated attempts and unnecessary motion.²³

At the same time, the review by Wiles et al. and related trauma-airway overviews make clear that no device is universally optimal, because blood, secretions, limited mouth opening, operator familiarity, and rescue capability all affect real-world performance.²⁴ This nuance is supported by the randomized immobilization studies in our sample, which show that performance differences persist not only between direct and video techniques but also among different videolaryngoscope blade designs and handling strategies.²⁴ Consequently, the strongest practice message is not that one instrument should replace all others, but that teams caring for spinal trauma should standardize a limited set of high-performing techniques that they use expertly and reproducibly.²⁴

Heterogeneity across the included studies was substantial and arose from differences in injury confirmation, neurological level, completeness of injury, care setting, timing definitions, airway operator background, and whether cervical injury was real or simulated.²⁵ Outcome heterogeneity was also significant, with studies variously reporting first-pass

success, intubation time, cervical motion, pneumonia, ventilation duration, decannulation, dysphagia, or hospital utilization rather than a unified core outcome set.²⁵ These features limited the feasibility of meaningful quantitative pooling beyond the tracheostomy-timing literature and support the decision to treat the overall synthesis primarily as qualitative.²⁵

The certainty of evidence according to GRADE would likely be judged low to moderate for most clinically important outcomes, because even where effect estimates were consistent, the body of evidence was dominated by retrospective cohorts and indirect simulation studies rather than large pragmatic randomized trials in actual trauma settings.²⁶ Confidence is highest for the broad association between earlier tracheostomy and shorter ventilation or length of stay, moderate for the technical advantage of videolaryngoscopy under immobilization, and lower for diaphragm pacing, extubation prediction tools, and decannulation predictors because those areas remain based on narrower datasets.²⁶ Publication bias cannot be excluded, particularly in device-comparison trials and retrospective single-center analyses that may preferentially report favorable procedural results.²⁶

From a clinical standpoint, the review supports a pragmatic airway pathway in which preoxygenation and preparation for first-pass success are prioritized, videolaryngoscopy is often favored for initial tracheal intubation when cervical motion restriction is required, and the threshold for early tracheostomy is lowered in patients with severe high cervical injury and anticipated prolonged ventilatory support.²⁷ It also suggests that swallowing assessment, pneumonia prevention, and decannulation planning should be viewed as core components of airway management rather than late rehabilitation concerns.²⁷ In practice, this means that airway care in traumatic spinal cord injury should be multidisciplinary from the outset, with close coordination among prehospital clinicians, emergency physicians, anesthesiologists, spine surgeons, intensivists, respiratory therapists, and rehabilitation teams.²⁷

For research, the field now needs multicenter prospective studies that enroll patients with confirmed traumatic spinal cord injury during real emergency care, compare modern airway strategies under standardized definitions, and report neurologic as well as respiratory outcomes.²⁸ Future trials should also distinguish cervical immobilization simulations from true unstable trauma, incorporate patient-centered endpoints such as aspiration burden and decannulation success, and evaluate how tracheostomy timing interacts with surgical decompression, sedation practice, and rehabilitation access.²⁸ Until those data emerge, the current evidence most strongly supports expert videolaryngoscopic airway management for initial instrumentation and an individualized but generally early tracheostomy strategy for patients at high risk of prolonged respiratory failure after traumatic cervical spinal cord injury.²⁸



6 CONCLUSION

The current evidence indicates that airway management in patients with traumatic spinal cord injury should be understood as a longitudinal process rather than as an isolated intubation event. The most consistent findings across the included literature favor strategies that maximize first-pass success, minimize unnecessary cervical motion, and anticipate prolonged respiratory support in patients with severe cervical injury. Videolaryngoscopy emerged as the most consistently advantageous approach for initial airway instrumentation under cervical motion restriction, while earlier tracheostomy was repeatedly associated with shorter ventilation time, shorter intensive care exposure, and fewer pulmonary complications. Adjunctive strategies such as structured extubation assessment, swallowing surveillance, and selected use of diaphragm pacing may further improve respiratory trajectories in carefully chosen patients.

The clinical relevance of these findings is substantial because airway decisions in traumatic spinal cord injury directly influence neurological protection, gas exchange, complication burden, and resource utilization. In practical terms, clinicians should prioritize thorough preparation, optimal preoxygenation, rapid access to rescue devices, and a technique that the team can perform with high reliability under trauma conditions. Patients with high cervical lesions, severe neurological impairment, or early signs of prolonged ventilatory dependence should be identified promptly for intensified respiratory planning and timely consideration of tracheostomy. These measures may help reduce preventable deterioration and support more coordinated care from the emergency setting through intensive care and rehabilitation.

The main limitations of the available literature must be acknowledged. Much of the evidence remains observational, retrospective, and heterogeneous, with relatively few randomized trials and limited direct research performed in real-world unstable trauma scenarios involving confirmed traumatic spinal cord injury. A considerable proportion of the intubation evidence derives from immobilization models, elective cervical spine surgery, or mixed cervical trauma populations, which reduces direct applicability to severe polytrauma. In addition, differences in timing definitions, outcome measures, airway devices, and patient selection complicate direct comparison across studies and limit the strength of pooled conclusions.

Future research should focus on prospective multicenter studies enrolling patients with confirmed traumatic spinal cord injury during actual emergency and critical care management. Such studies should compare contemporary airway strategies using standardized definitions of cervical motion restriction, first-pass success, hypoxic events,



neurological outcomes, pneumonia, extubation success, and decannulation. There is also a need for more rigorous investigation into the optimal timing of tracheostomy, the role of diaphragm pacing in acute and subacute phases, and the integration of swallowing and respiratory rehabilitation into airway protocols. Development of a core outcome set for this population would substantially improve comparability and strengthen future evidence synthesis.

Overall, the management of the airway in traumatic spinal cord injury requires evidence-based, multidisciplinary, and individualized decision-making. The best current approach is one that combines technically proficient initial airway control with early recognition of longer-term respiratory needs and careful coordination among emergency physicians, anesthesiologists, spine surgeons, intensivists, respiratory therapists, and rehabilitation teams. Rather than relying on rigid dogma, clinicians should adapt airway strategy to the neurological level of injury, physiological instability, expected respiratory course, and local expertise. This individualized and integrated model is the most defensible pathway for improving safety and outcomes in this high-risk population.

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