Prehospital spinal and cervical motor restriction in adult trauma patients: a narrative review

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Abstract

The prehospital motor restriction of the cervical and spinal column in trauma patients remains a highly debated topic, with significant variability in clinical practice. With the present study, we aimed to conduct a narrative review of the literature on cervical and spinal motor restriction in prehospital settings, identifying devices used, clinical decision-making tools, and potential complications. A structured search was conducted in four databases (PubMed, ProQuest, CINAHL, Web of Science), including studies on adult trauma patients (≥16 years) with suspected spinal injury in prehospital settings. Screening was performed using Rayyan QCRI, and methodological quality was assessed via the Kmet checklist. A total of 28 studies were included. Evidence highlights that immobilization should not be applied routinely but guided by clinical risk and context. The use of validated protocols, selective motor restriction, and alternative devices (e.g., vacuum mattresses, self-extrication) may improve outcomes and reduce complications. High-fidelity simulation training and clinical audits are recommended to enhance decision-making and protocol adherence in spinal trauma management.

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Introduction

Traumatic injuries of the cervical and spinal column represent a clinical emergency that can significantly impact both survival and the long-term quality of life of affected patients. Although relatively uncommon—accounting for an estimated 1% to 3% of major trauma cases—the neurological and functional consequences can be devastating.[1,2] Since the 1970s and 1980s, growing concern regarding the prevention of secondary neurological damage has led to the widespread adoption of prehospital spinal immobilization as a routine intervention.[3,4] Historically, educational protocols such as ATLS, PHTLS, and the guidelines of the National Association of EMS Physicians (NAEMSP) have advocated for a systematic approach to spinal immobilization in the presence of potentially unstable trauma, even in the absence of overt neurological signs.[5-6] The underlying rationale was based on the hypothesis that even minimal micromovements could exacerbate a pre-existing vertebral injury. However, over the past two decades, an increasing body of literature has questioned the actual clinical effectiveness of this procedure.[2,7,8]

This evolving skepticism has also been reflected in a conceptual and terminological shift. In recent years, the term Spinal Motion Restriction (SMR) has increasingly replaced spinal immobilization in international consensus documents and clinical guidelines. According to a joint position statement by the American College of Surgeons Committee on Trauma, the American College of Emergency Physicians, and the National Association of EMS Physicians, current prehospital techniques do not achieve true immobilization but aim to reduce unwanted spinal motion to the minimum necessary. As such, SMR thus better reflects the clinical goal of minimizing secondary spinal injury while limiting patient discomfort and potential complications.[9]

Numerous critical reviews and observational studies have highlighted that routine spinal immobilization may not improve neurological outcomes and, conversely, may be associated with potentially avoidable complications. These include pressure ulcers, respiratory distress, increased intracranial pressure, delayed airway management, and anxiety in conscious patients. In a large cohort of patients with spinal injury, a higher incidence of adverse events was reported in the immobilized group, without documented neurological benefits.[10-13]

Concurrently, the literature has documented widespread overuse of the procedure: Mitchnik *et al.* reported that only 8% of patients fitted with a cervical collar had a radiologically confirmed cervical injury,[14] while Lee *et al.* observed a collar application rate exceeding 70% in polytrauma patients, regardless of the presence of clinical risk criteria.[15] To complicate the scenario further, evidence indicates that in specific subgroups—such as patients with traumatic brain injury or those in cardiac arrest—spinal immobilization may be not only unnecessary, but potentially harmful.[2,16] In response to this issue, clinical decision tools have been developed to more accurately identify patients who require spinal immobilization. The NEXUS criteria and the Canadian C-Spine Rule (CCR) have demonstrated high sensitivity in detecting clinically significant injuries while simultaneously reducing unnecessary use of immobilization devices.[17,18]

More recently, Häske *et al.* proposed the Immo TLS system, a traffic-light algorithm that integrates epidemiological, neurological, and mechanical factors into the prehospital decision-making process.[19] Studies conducted in the Netherlands, Germany, and South Korea have shown that adopting selective immobilization protocols can significantly reduce cervical collar use without compromising patient safety.[15,20,21]

The scoping review conducted by Habibi Arejan *et al.*, based on 42 international studies, emphasized that practices remain heterogeneous and are often influenced by organizational, cultural, and medico-legal factors.[22] Moreover, the implementation of clinical decision protocols frequently encounters obstacles such as incomplete training and the lack of continuous professional development among emergency responders.[7,17]

The literature also indicates that improper application of cervical collars by untrained personnel may result in paradoxical cervical movements or incorrect immobilization, potentially increasing clinical risk.[16,23] In terms of devices, alternatives to the Long Spine Board (LSB), such as the vacuum mattress and scoop stretcher, have been proposed. These appear to offer superior performance in terms of comfort, stability, and pain reduction.[24,25] Experimental studies have also demonstrated that, in stable patients, controlled self-extrication produces less cervical spine movement compared to passive extraction using an LSB.[8]

Despite the growing body of evidence, significant gaps remain in the literature, particularly concerning the role of immobilization in penetrating trauma, in elderly patients, in rural environments, and in high-demand operational settings. Furthermore, it is necessary to assess the economic, organizational, and psychological impacts associated with the widespread use of spinal immobilization devices.[4,21,22]

In light of these considerations, the present narrative review aims to critically analyze the available evidence on the clinical effectiveness of prehospital spinal immobilization, with specific attention to associated complications, device comparisons, the implementation of selective decision criteria, and the persistent gaps in the literature. The objective is to provide a concise yet comprehensive overview to support clinical practice in emergency medical systems.

Materials and Methods

This narrative review was conducted in accordance with the criteria proposed by the Scale for the Assessment of Narrative Review Articles (SANRA), in order to ensure methodological rigor and scientific consistency.[26] The search strategy was structured and documented through the use of MeSH terms and Boolean operators. The article selection process was carried out in two phases: an initial screening based on the relevance of title and abstract, followed by full-text evaluation conducted in a double-blind manner by independent reviewers. To enhance the transparency of the process, a flowchart inspired by the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) was developed, summarizing the stages of study identification, inclusion, and exclusion.[27] The methodological quality of the included studies was assessed using the Kmet checklist, a critical appraisal tool designed to evaluate primary research across different fields of study. The critical appraisal was independently performed by two reviewers using the Kmet checklist. Each study was assigned a summary score expressed as a percentage of applicable criteria. An inclusion threshold of ≥75% was adopted to determine high methodological quality. Inter-rater reliability on inclusion decisions was quantified using Cohen's kappa coefficient, yielding a value of 0.200 and a raw agreement rate of 56.3%, indicative of slight agreement. Given the qualitative nature of the tool, discrepancies were resolved through consensus to ensure consistency in study selection. A comparative summary of individual reviewer scores is provided in *Supplementary materials, Table 2*.

Search strategy

The search strategy was developed in a structured and reproducible manner, with the support of a research methodology expert. Four electronic databases were consulted: PubMed, ProQuest, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Web of Science. The search was conducted up to March 11, 2025, using combinations of MeSH terms (where available) and free-text keywords, connected via Boolean operators ("AND", "OR"). The strategy was adapted to the syntax of each specific database. The main search terms included: "cervical spinal", "cervical cord", "spinal trauma", "spinal board", "adult", "immobilize", "device", "emergency medical services". The results obtained (n = 348) were exported and uploaded to the Rayyan platform – Qatar Computing Research Institute (QCRI), where a double-blind screening was conducted by two independent reviewers. Any disagreements were resolved through discussion and consensus with a third reviewer. Study selection was carried out in two phases: an initial screening of title and abstract, followed by a full-text review of eligible studies.

Eligibility criteria

Studies were considered eligible if they examined adult patients (age >16 years) with suspected cervical and/or spinal injuries in prehospital emergency settings. Only studies involving mechanical or blunt trauma were included, while those involving penetrating trauma (e.g., stab wounds, gunshot injuries) or non-traumatic spinal conditions were excluded. Both primary research articles (observational studies or clinical trials) and secondary studies were considered eligible. Only articles published in English or in Italian with an abstract available in English were included. Full-text availability was required for inclusion in the qualitative synthesis. Exclusion criteria included studies involving pediatric populations (<16 years), research conducted exclusively in hospi-

tal, military, sports, or simulated environments, and studies on chronic, degenerative, or non-traumatic spinal conditions. Letters, editorials, conference abstracts without full text, and opinion papers lacking a structured methodology were also excluded.

Study selection

The initial search returned a total of 348 records from the four selected databases. After automatic and manual removal of duplicates, the remaining studies were subjected to a two-phase selection process using the Rayyan QCRI platform. In the first phase, two independent reviewers assessed titles and abstracts against the predefined eligibility criteria. Articles deemed potentially relevant were then evaluated in full-text form during the second phase. Discrepancies between reviewers were resolved through discussion and consensus with an expert reviewer. At the end of the selection process, 28 articles were included in the qualitative synthesis. The study selection process is illustrated in a PRISMA-style flowchart (Figure 1), which outlines the phases of identification, screening, inclusion, and exclusion.[28] The characteristics, methods, and main findings of the included studies are summarized in Appendix 2. The selection process was guided by the primary outcome, namely the identification of evidence concerning the most appropriate modality of cervical and spinal immobilization in adult trauma patients in prehospital settings, as described in the PCC Framework (*Supplementary materials, Table 2*).[29]

Narrative synthesis of results

Clinical effectiveness of spinal immobilization

Several studies have investigated the clinical effectiveness of prehospital spinal immobilization in terms of neurological and functional outcomes. Chen *et al.* conducted a multicenter study involving 759 patients and found that prehospital immobilization was not associated with improvement in overall functional outcome (aOR 1.06; p = 0.826). However, in a subgroup analysis, patients with cervical injuries showed significantly improved outcomes (aOR 3.14; 95% CI 1.04–9.50).[1] Mitchnik *et al.* analyzed 220 patients with blunt trauma and found that only 8% of those wearing a cervical collar had a radiologically confirmed cervical injury, suggesting potential overuse of the device without clear clinical benefit.[14] Yue *et al.*, in a cohort of 3,356 patients, reported that immobilization did not improve neurological outcomes and was associated with an increased risk of complications.[13] These findings are consistent with the review by Sundstrøm *et al.*, which highlighted the lack of robust evidence supporting the neurological benefit of routine immobilization.[2]

Comparison of immobilization devices and techniques

Stuby *et al*. compared vacuum mattresses with rigid spinal boards (LSB), reporting significantly reduced lateral (5.1° *vs*. 12.7°) and anteroposterior movements (3.4° *vs*. 9.2°), and greater patient comfort (VAS 8.1 *vs*. 5.4).(25) Kon Jin *et al.*, in a systematic review, found that rigid cervical collars reduce cervical spine motion by 30% to 60%, but do not ensure complete immobilization.[30] Dixon *et al.* assessed the efficacy of controlled self-extrication versus passive movement using an LSB, demonstrating less cervical motion in conscious and cooperative patients (13.3° *vs*. 18.8°).[8]

Selective approaches and decision-making tools

Vaillancourt *et al.* validated the Canadian C-Spine Rule (CCR) in prehospital settings, showing a 40% reduction in unnecessary

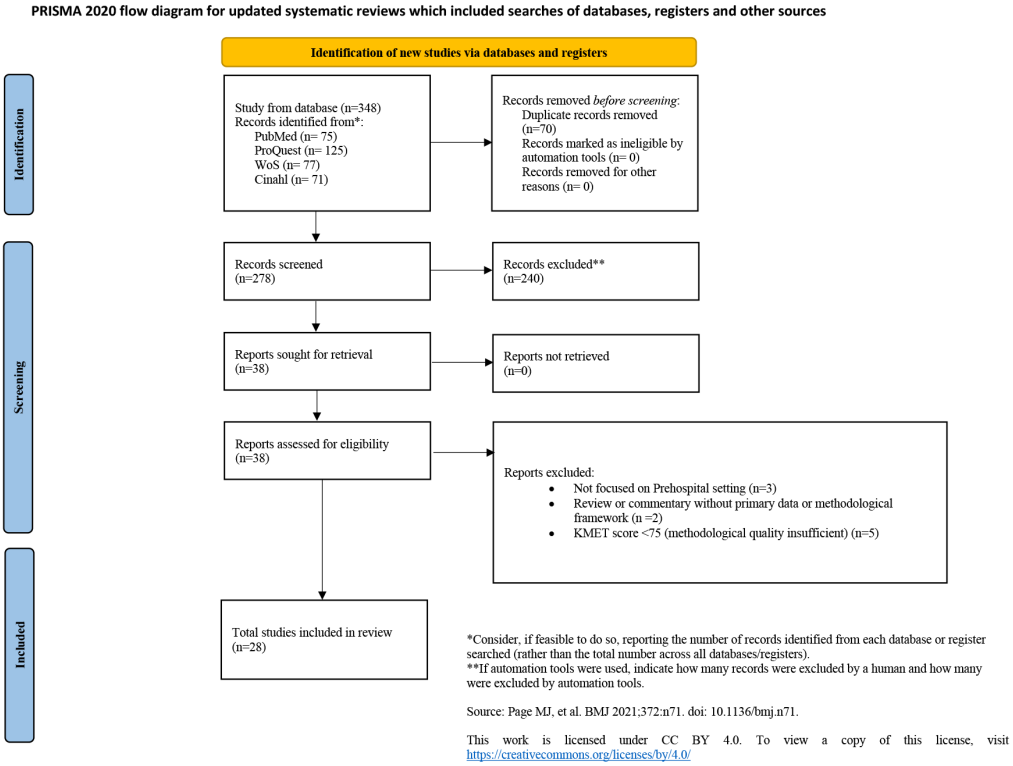

Figure 1. PRISMA flow.

collar use, with 100% sensitivity and no missed injuries.[17] Häske *et al.* proposed the Immo TLS, a traffic light-based clinical algorithm, which—across more than two million cases—demonstrated a reduction in unnecessary collar use by identifying patients through objective criteria.[19] The review by Habibi Arejan *et al.* reported that, despite the availability of validated tools such as NEXUS and CCR, their real-world application remains inconsistent across healthcare systems.[22] Lee *et al.* observed that fewer than 50% of healthcare professionals were familiar with CCR/NEXUS criteria, underscoring the need for ongoing training and education.[15]

Complications associated with immobilization

Yue *et al.* found higher rates of complications such as pressure sores and infections in immobilized patients.14 Kwan *et al.* emphasized that immobilization can impair ventilation, reduce vital capacity, and increase intracranial pressure, particularly in patients with head trauma.[7] Peery *et al.* found that only 48% of immobilization procedures met technical quality standards, highlighting the risks associated with incorrect application.[31] Hood and Considine, in a systematic review, documented frequent adverse effects—such as pain, respiratory difficulty, claustrophobia, and pressure ulcers—in the absence of demonstrated neurological benefit.[10]

Populations and specific contexts

Häske *et al.* identified age over 65, head trauma, high-energy mechanisms, and peripheral neurological deficits as key predictors of spinal instability.[32] Lee *et al.* reported that collar application in patients with head trauma and GCS < 9 was associated with increased mortality (OR 1.85; 95% CI 1.24–2.76), indicating potential iatrogenic risk.[15] Dixon *et al.* showed that, in remote settings and with cooperative patients, self-extrication may be safer than forced immobilization.[8] Finally, Habibi Arejan *et al.* highlighted the lack of research in low-resource settings, among frail populations, and in cases of penetrating trauma, calling for further investigations.[22] Overall, the findings suggest that spinal immobilization should be based on selective clinical criteria rather than applied indiscriminately. The available evidence supports a patient-centered approach that considers individual characteristics, operational contexts, and available resources.

Discussion

The findings of this narrative review confirm a substantial shift in the prehospital management of patients with suspected spinal trauma. Routine spinal immobilization, long considered the gold standard, is now supported by weak clinical evidence—especially in low-risk patients. This evolving paradigm has also led to a terminological shift: the concept of SMR has increasingly replaced spinal immobilization in recent guidelines and position statements. SMR emphasizes the goal of minimizing unnecessary spinal motion rather than achieving complete immobilization, reflecting a more realistic and patient-centered approach to prehospital care.[9] Recent studies have demonstrated the lack of neurological benefit associated with routine immobilization, except in select subgroups such as those with confirmed cervical injuries.[1,13,14] In parallel, the risk of complications associated with the procedure is consistently documented in the literature.[7,10,31] Comparative studies have demonstrated the biomechanical and comfort superiority of vacuum mattresses over rigid spine boards, as well as the safety of controlled self-extrication in cooperative patients.[8,24] These findings suggest that device selection should be guided by clinical criteria, patient stability, and operational context. Additionally, variability in device application technique is a critical issue that reinforces the need for continuous provider training.[31]

The adoption of selective protocols based on validated tools (NEXUS, CCR, Immo TLS) emerges as one of the main recommendations from the literature. The implementation of the Canadian C-Spine Rule and Immo TLS has been shown to reduce inappropriate collar use without increasing the risk of missed injuries.[17,19,33] However, dissemination of these tools remains inconsistent, hindered by organizational and educational barriers.[15,22] The risk of overuse in elderly patients, individuals with head trauma, and in low-resource contexts is another key concern.[15,32] In particular, the increased mortality associated with collar use in patients with GCS < 9 calls for caution in applying cervical immobilization automatically in this population. Moreover, the lack of high-quality studies in remote environments, resource-limited settings, and penetrating trauma limits the generalizability of current recommendations.[22]

Taken together, the available data support a model of prehospital spinal immobilization based on clinical appropriateness rather than procedural automatism. Patient selection, risk assessment, provider training, and the systematic adoption of decision-making tools are essential for delivering modern, effective, and safe clinical care.

Conclusions

Based on the available evidence, spinal immobilization in the prehospital setting should not be applied routinely, but rather evaluated based on clinical risk, patient condition, and operational context. This principle aligns with the concept of Spinal Motion Restriction (SMR), which emphasizes the reduction of unnecessary spinal motion rather than the achievement of complete immobilization. The adoption of SMR terminology reflects a more pragmatic and patient-centered approach to prehospital spinal care.[10] The literature review shows that the effectiveness of the intervention is limited to specific subgroups, while associated complications and the risk of overtreatment remain high.

Alternative devices, self-extrication strategies, and validated clinical decision protocols are valuable tools for achieving more rational and safe management. Continuous training of providers, updates to local protocols, and further studies on at-risk populations, penetrating trauma, and low-resource settings are necessary. The adoption of an evidence-based decision-making model for spinal immobilization has the potential to improve clinical outcomes, reduce complications, and optimize the use of resources in prehospital emergency systems. In addition, future directions should emphasize the role of high-fidelity simulation-based training as a means of improving provider decision-making and technical skills, as well as the systematic implementation of clinical audits to monitor adherence to protocols and support continuous quality improvement.

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Online supplementary materials:
Table 1
Table 2

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