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Clinical Reviews

Cervical Spine Clearance in Adult and Pediatric Trauma: A Systematic Review

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☐ Abstract—Background: Cervical spine clearance after trauma is essential for preventing secondary neurologic injury while avoiding unnecessary immobilization and imaging. Advances in computed tomography (CT) and standardized clinical decision rules such as National Emergency X-Radiography Utilization Study and the Canadian C-Spine Rule have changed protocols for adult and pediatric patients. Objectives: This systematic review aims to compile current evidence to identify safe, effective, and evidence-based methods for cervical spine clearance. Methods: A PubMed/MEDLINE systematic search was conducted through October 2025 for studies evaluating cervical spine clearance in adult and pediatric trauma patients. Eligible studies analyzed clinical decision tools or imaging modalities (such as physical examination, radiography, CT, magnetic resonance imaging [MRI], ultrasound) and reported on diagnostic accuracy, safety, or workflow outcomes. Data was extracted and narratively synthesized due to methodological heterogeneity. Results: Thirty-three adult and eleven pediatric studies met the inclusion criteria. In adults, multidetector CT with multiplanar reconstructions achieved 98–100% sensitivity and >99% negative predictive value for clinically significant or unstable injury, supporting collar removal after a normal CT even in obtunded or intoxicated patients. MRI detected additional findings in 0.4–3% of cases, rarely changing management. In children, structured clinical protocols combining physical examination and plain radiography safely reduced CT use by up to 70%, with MRI reserved for persistent symptoms or ligamentous concerns. Conclusion: Modern multidetector CT is the gold standard for adult cervical spine clearance, while pediatric management favors radiation-sparing, protocol-based approaches. Evidence supports tiered, algorithmic strategies emphasizing clinical assessment, selective imaging, and early collar removal to optimize safety and efficiency in trauma care.

☐ Keywords—Cervical spine clearance; adult; pediatric; trauma; Canadian C-Spine Rule (CCSR); NEXUS criteria

Introduction

Trauma teams must quickly and safely clear the cervical spine to prevent secondary neurologic injury while avoiding unnecessary immobilization and imaging. The burden on the population is significant: pooled estimates indicate a cervical spine injury (CSI) prevalence of approximately 3.7% among all trauma patients, around 2.8% in alert patients, and roughly 7.7% in unevaluable patients, with approximately 42% of cervical spine injuries classified as unstable lesions, carrying a substantial risk of neurologic deterioration (1). Extended collar use and board immobilization pose risks—including pressure ulcers, airway difficulties, increased intracranial pressure, discomfort, and prolonged emergency department stays—making timely clearance a priority for patient safety and system efficiency (2). Current trauma frameworks, therefore, have standardized pathways for assessment, imaging, and col-

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lar removal integrated into institutional protocols, aiming to maintain high sensitivity for detecting clinically significant CSI while avoiding resource overuse (2).

For alert, cooperative adults, validated clinical decision instruments—the National Emergency X-Radiography Utilization Study (NEXUS) low-risk criteria and the Canadian C-Spine Rule (CCR)—allow selective imaging and earlier collar removal. The original NEXUS validation (>34,000 patients) demonstrated very high sensitivity for clinically significant CSI, supporting safe avoidance of radiography in low-risk cases (3). In head-to-head prospective comparisons, the CCR achieved higher sensitivity and specificity than NEXUS and would have reduced imaging rates, underscoring its usefulness among clinicians who are trained and comfortable with applying range-of-motion testing (4,5). When imaging is indicated, non-contrast multidetector computed tomography (CT) with multiplanar reconstructions is now the first-line in adult blunt trauma pathways; radiographs are mostly deprioritized, and routine magnetic resonance imaging (MRI) is not recommended for low-risk patients without neurologic deficits (6). Major guidelines (American College of Radiology [ACR] Appropriateness Criteria 2024 update; American College of Surgeons [ACS] Best Practices 2022) converge on CT-based clearance for both examinable and unexaminable adults, while recognizing that center-level differences exist in the use of adjunct MRI for CT scans that are inconclusive or for unexplained neurologic findings (2,6). Advanced Trauma Life Support (ATLS) teaching further supports stopping immobilization in many clinically low-risk patients based on CCR/NEXUS criteria without mandatory imaging, highlighting a pragmatic focus on thorough examination and judicious testing (7,8) (Table 1). In obtunded or otherwise unreliable examinations, clearance must be guided by imaging. High-quality CT scans (thin-slice axial with sagittal and coronal reconstructions) are recommended as the initial test, with institutions tailoring the use of MRI when CT results are inadequate, or symptoms persist despite negative CT (2,6,9).

Pediatric protocols remain more cautious: decision rules are less validated, ligament injury patterns vary, and thresholds for imaging and consultation are usually lower, often based on ATLS principles and pediatric adaptations (7). Compared with adults, pediatric cervical spine clearance remains less standardized. Clinical decision rules such as NEXUS and CCR are less well validated in children, particularly in younger age groups, because of developmental anatomy, a higher prevalence of ligamentous injury, and concerns about radiation exposure. As a result, pediatric protocols often emphasize careful clinical examination, selective use of plain radiography, and conservative thresholds for CT or MRI, frequently incorporating delayed reassessment or specialist consultation. These differences reinforce the need for age-specific, radiation-sparing clearance strategies and justify separate consideration of adult and pediatric evaluations.

Amid evolving technology and practice differences, our systematic review synthesizes adult and pediatric evidence on clinical rules (NEXUS, CCR), imaging options (radiography, CT, MRI), and clearance protocols across different reliability levels, aiming to reduce missed unstable injuries and mitigate the harms from over-immobilization and excessive imaging (2–7,9).

Methods

Search Strategy

A systematic search of PubMed/MEDLINE was conducted from database inception to October 2025 to identify studies evaluating cervical spine clearance in trauma among adult and pediatric populations. The search combined controlled vocabulary (MeSH terms) and free-text keywords related to *cervical spine, trauma, clearance*, and *diagnostic evaluation*. The Boolean strategy included:

> (“Cervical Vertebrae” OR “Cervical Spine” OR “Cervical Injury” OR “Cervical Trauma” OR “Cervical Spine Injury”) AND (“Triage” OR “Clearance” OR “Evaluation” OR “Assessment” OR “Algorithm” OR “Guideline”) AND (“Radiography” OR “X-ray” OR “Plain Film” OR “CT” OR “Computed Tomography” OR “MRI” OR “Magnetic Resonance Imaging”) AND (“Physical Examination” OR “Neck Pain” OR “Glasgow Coma Scale” OR “GCS” OR “Glasgow”) AND (“Trauma” OR “Injury” OR “Blunt Trauma” OR “Spinal Injuries”).

For pediatric studies, the search string was restricted to publications from 2015 to 2025 using the terms “Cervical Spine Clearance” and “Pediatric” to reflect contemporary clearance protocols, imaging practices, and radiation-sparing strategies, as earlier pediatric approaches were largely extrapolated from adult decision rules and predate modern CT technology. Additionally, preliminary scoping searches demonstrated that the vast majority of pediatric clearance studies meeting inclusion criteria were published after 2015. The reference lists of all included papers and relevant reviews were manually screened to identify additional eligible studies. Only English-language publications were included. This search design followed methodological frameworks described by Lu et al. (10) and Muka et al. (11).

Eligibility Criteria and Study Selection

Eligible studies met the following criteria: 1) focused on cervical spine clearance in trauma; 2) involved adult or

Table 1. Summary of Cervical Spine Clearance Approaches By Clinical Scenario, Outlining Examination Reliability, Recommended Imaging Modalities, and Considerations Based on Recent Guideline Consensus (2–7).

Scenario	Criteria/Approach	Imaging/Clearance	Notes
Examinable, alert, reliable patient	Must satisfy reliability (GCS 15, no intoxication, no distracting injury, no language barrier, able to cooperate)	Use clinical decision rules (NEXUS or CCR) to decide whether imaging is needed	CCR tends to outperform NEXUS (higher specificity) in many studies, with equally high sensitivity
	If they pass the clinical rule (i.e., "low risk"), no imaging may be required; collar removed	If the rule indicates imaging, the preferred first test is noncontrast cervical spine CT with multiplanar reconstructions	
Examinable but with red flags or unreliable exam	e.g., Midline tenderness, neurologic symptoms, distracting injuries, age >65, mechanism of injury	Obtain CT C-spine	Some centers consider MRI or further imaging if CT ambiguous or shows concerning but nondisplaced findings
Unexaminable/ obtunded/altered mental status/intubated	Clinical exam not reliable	Proceed directly to high-quality CT (axial ≤ 3 mm, multiplanar reconstructions)	The key controversy: whether CT alone is sufficient to allow collar removal
	Conditional recommendation: in adults, many guidelines now support collar removal after negative, high-quality CT, without routine adjunct imaging, in selected patients	But decision should be individualized: if CT is suboptimal, if there is clinical suspicion, or if MRI is readily available, adjunct imaging may still be justified	
Persistence of neurologic findings or ambiguous imaging	If patient has neurologic deficits, signs of instability, or CT findings that raise suspicion (ligamentous injury, subluxation)	Further evaluation with MRI, flexion-extension studies, or dynamic radiographs (if safe)	MRI is especially useful for detecting disco-ligamentous injury and spinal cord compression when CT is negative or inconclusive
Pediatric patients	Children ≤16 years have different anatomy, higher risk of ligamentous injury (e.g., SCIWORA)	Many centers still begin with plain radiographs or CT, depending on resources; a cautious approach is taken	Clinical rules (NEXUS, CCR) are less well validated in children; many protocols rely more heavily on imaging and neurosurgical consultation

GCS = Glasgow Coma Scale; CCR = Canadian C-Spine Rule; NEXUS = National Emergency X-radiography Utilization Study Criteria; CT = computed tomography; MRI = magnetic resonance imaging; SCIWORA = spinal cord injury without radiography abnormality.

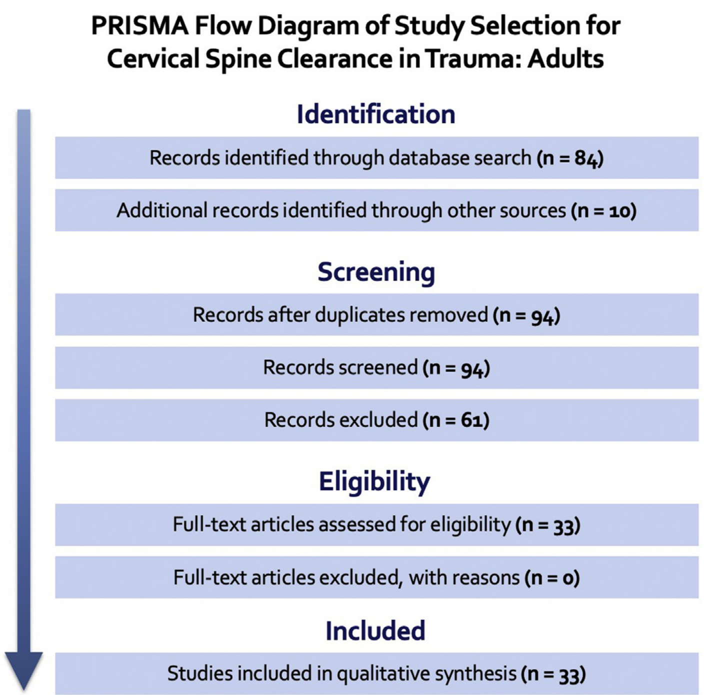

Figure 1. PRISMA flow diagram of study selection for cervical spine clearance in trauma: adults. Flow diagram illustrating the identification, screening, eligibility, and inclusion of studies in the adult population. The database search yielded 84 records, and 10 additional studies were identified through manual screening, for a total of 94 adult records screened. After duplicate removal and screening, 33 studies met the inclusion criteria and were included in the qualitative synthesis.

pediatric populations; 3) evaluated one or more diagnostic modalities or clinical decision instruments (e.g., NEXUS, CCR, CT, MRI, radiography, or physical examination); and 4) reported relevant outcomes on diagnostic accuracy, safety, or clinical workflow.

Exclusion criteria included case reports (<5 patients), narrative reviews without new data, technical notes, non-cervical spine trauma studies, and reports lacking patient-level outcomes. Two reviewers independently screened titles and abstracts, assessed full texts, and resolved disagreements by consensus.

The search yielded 84 articles (records), and an additional 10 studies were identified through manual reference screening, for a total of 94 adult records and 33 for pediatric populations. After applying inclusion and exclusion criteria, 23 adult and 11 pediatric studies were retained for synthesis (PRISMA 2020 flowcharts shown in Figures 1 and 2).

Data Extraction and Synthesis

For each study, we extracted information on study design, sample size, index test and comparator (physical examination, CT, MRI, X-ray, or ultrasound), primary outcome, and key findings. Because of substantial heterogeneity across study populations, clearance definitions, imaging protocols, and outcome measures, quantitative meta-analysis was not feasible; therefore, results were synthesized using a narrative comparative approach.

Results

Study Selection and Characteristics

In total, 94 adult articles (84 from database searching and 10 from additional sources) and 33 pediatric articles were identified. After screening and full-text assessment, 33 adult and 11 pediatric studies were included in the qualitative synthesis (PRISMA shown in Figures 1 and 2). Adult studies spanned 2008–2025 and comprised prospective and retrospective cohorts, multicenter trials, systematic reviews/meta-analyses, and narrative reviews; pediatric studies (2016–2025) included retrospective cohorts, an algorithm validation, and reviews.

Adult Trauma (Table 2)

Across large prospective cohorts and meta-analyses, modern multidetector CT with multiplanar reconstructions demonstrated very high negative predictive value (NPV ~99.2–99.97%) for clinically significant or unstable cervical spine injury (CSI), supporting collar removal after a normal CT in most adults, including many with unreliable examinations (e.g., intoxication).

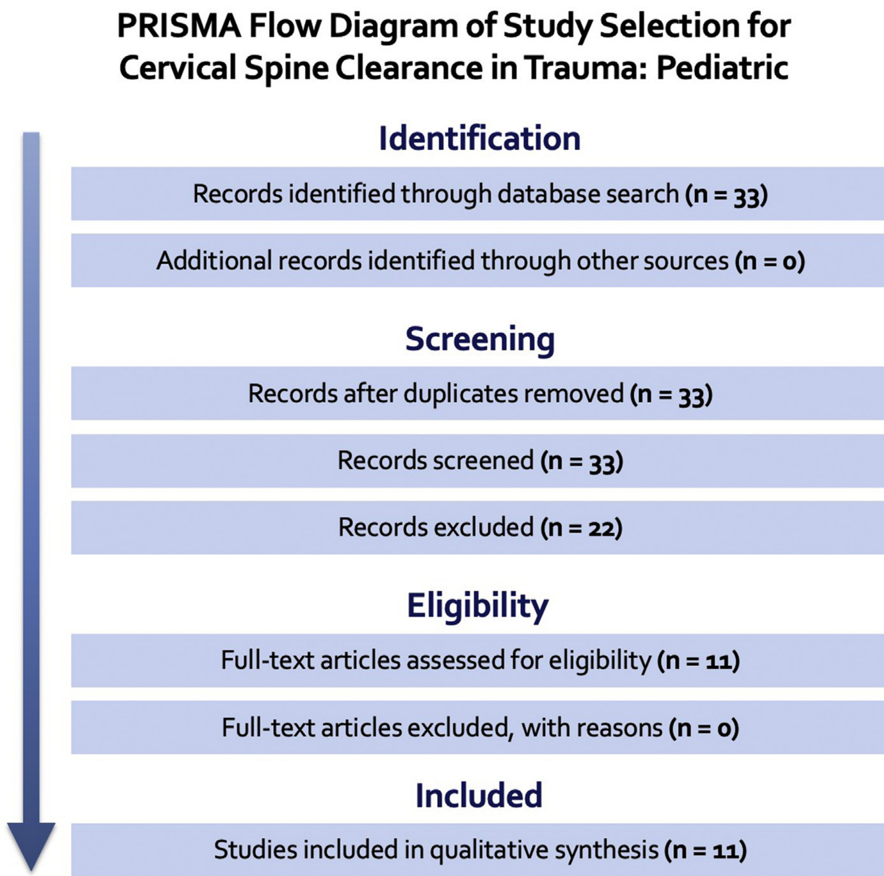

Figure 2. PRISMA flow diagram of study selection for cervical spine clearance in trauma: pediatric. Flow diagram depicting the study selection process for pediatric cervical spine clearance. A total of 33 records were identified through database search, with no additional sources. Following screening and eligibility assessment, 11 studies met the inclusion criteria and were included in the final qualitative synthesis.

Flexion–extension radiographs were often of low yield and frequently inadequate. When obtained after a negative CT, MRI detected additional abnormalities in a minority (often ligamentous or soft-tissue) and rarely led to changes in management (reported management change ~0.4–3%). However, some series and newer meta-analyses reported higher rates of "any injury" detection with MRI, with only small proportions requiring treatment, highlighting center-level variability and the value of targeted MRI for patients with persistent neurologic deficits or ambiguous CT results. Additional operational findings included significant variation between centers in MRI use after negative CT and prolonged collar times, even with negative CT, both of which improved with protocolized post-CT clinical reassessment. Studies in specific subgroups suggested: a) alert patients with distracting injuries can be clinically cleared without missing significant CSI; b) in older adults after low-energy mechanisms, physical examination alone has limited sensitivity, favoring liberal use of CT (39); and c) point-of-care ultrasound may be a helpful adjunct in resource-limited settings but should not replace CT (35). Overall, adult data support a CT-first, MRI-when-needed approach and de-emphasize the use of flexion–extension radiographs (Table 2).

Pediatric Trauma (Table 3)

Pediatric evidence emphasizes radiation stewardship and the use of clinical algorithms. Several cohorts show that structured clinical pathways, "next-day" examinations, and plain radiographs allow for clearance in most evaluable children with very high negative predictive values (NPVs), while decreasing CT use without missing clinically significant injuries. When CT is performed, its specificity is high; however, MRI may detect ligamentous injuries after a normal CT in selected cases, supporting MRI targeting when symptoms persist or examination is unreliable. The performance of algorithms and scoring tools varies: some scores (e.g., PEDSPINE I) have limited sensitivity (51), and reviews emphasize high sensitivity but low specificity across tools, with insufficient

Table 2. Summary of Studies Assessing Cervical Spine Clearance in Adult Trauma patients. The Table Presents Study Design, Population, Diagnostic Modality Comparisons, and Findings Regarding the Accuracy and Safety of CT, MRI, X-ray, and Physical Examination-Based Clearance Algorithms.

Study (First Author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
Dunham (12)	2008	USA	Narrative review (120 references)	–	Early collar removal vs. MRI/prolonged collar	CT-negative instability risk 2.5%; collar complications 26%; MRI risks higher; prioritize early clearance
Anderson (13)	2010	USA	Systematic review 14 studies)/meta-analysis	61,989 patients	Physical exam-based clearance (NEXUS/CCR) vs. Radiography/CT	Sensitivity 98%, NPV 99.9%; clinical clearance safe in low-risk, alert patients
Hennessy (14)	2010	Canada	Prospective cohort	402 patients	CT vs. X-ray (flexion–extension)	1/402 missed on CT (interpretation error); CT alone sufficient for clearance; F–E not supported
Fisher (15)	2013	USA	Retrospective cohort	277 patients	CT alone vs. CT + MRI	5% additional injuries found on MRI; 3% management change; NNS = 21 for significant injury
Raza (16)	2013	UK	Retrospective cohort/meta-analysis	1903 patients (1853 meta-analysis, 53 local cohort)	CT vs. MRI or clinical follow-up	Pooled NPV 99.7% for CT; no clinically significant injuries missed; supports clearance after normal CT
Tan (17)	2014	USA	Retrospective cohort	83 patients	CT vs. MRI	CT sensitivity and specificity 100% for unstable injuries; MRI added only non-unstable findings; CT alone safe for clearance
Patel (18)	2015	USA	Systematic review/meta-analysis	1017–1718 patients across studies	CT vs. CT + MRI/upright X-rays/clinical follow-up	Conditional recommendation to remove collar after negative high-quality CT alone; 0–9% stable injuries, none unstable

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Table 2. (*continued*)

Study (First Author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
Mavros (19)	2015	USA	Retrospective cohort	383 patients	CT vs. MRI/flexion-extension/repeat exam	No significant injuries on additional imaging; collars safely removed after CT and repeat exam; routine further imaging unnecessary
Mejaddam (20)	2015	USA	Prospective cohort	1007 patients (841 GCS 15, 166 GCS < 15)	CT (Loss of Lordosis, [LOL]) vs. MRI/flexion-extension/serial exam	No significant injuries when isolated LOL was only finding; 0.3% minor MRI findings without clinical relevance; isolated LOL should not prevent clearance
Bush (21)	2016	USA	Prospective cohort	1668 patients (632 intoxicated)	CT vs. continued collar/additional imaging	CT NPV 99.2% for any CSI, 99.8% for unstable injuries; one missed ligament injury; CT-based clearance appears safe in intoxicated without deficits
Duane (22)	2016	USA	Prospective cohort	9227 patients	CT with selective MRI	6% had injury (all fractures); no injury with normal CT; MRI for deficits or suspicious patterns; supports CT-only clearance in most cases
Inaba (23)	2016	USA	Prospective cohort (multicenter, WTA)	10,276 patients	CT with follow-up $\pm$ MRI	CT sensitivity 98.5%, specificity 91%, NPV 99.97%; three false negatives—all with focal neuro deficits; MRI indicated for neuro deficits
Oh JJ (24)	2016	Australia	Narrative review 62 references)	–	Flexion-extension X-ray vs. CT	F/E radiographs frequently inadequate and have low diagnostic yield; add no value after CT; not recommended for obtunded patients

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Table 2. (*continued*)

Study (First Author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
Chilvers (25)	2017	England	Cross-sectional study	–	CT (initial) vs. MRI (adjunct)	72% use CT as first-line; 52% perform MRI after normal CT; most follow national guidelines
Huh Lau (26)	2017	Singapore	Retrospective cohort	63 patients	CT vs. MRI	CT specificity 100%, sensitivity 87%; MRI-only findings associated with female sex, mild mechanism, thoracic injury, and ICH; MRI reserved for selected patients
Martin (27)	2017	USA and Canada	Prospective cohort (multicenter, WTA)	10,191 patients (~30% intoxicated)	CT vs. continued collar/additional imaging	CT NPV 99.9% for significant and 100% for unstable injuries; prolonged collar time despite negative CT; supports CT-based clearance in intoxicated without deficits
Veiga (28)	2018	UK	Systematic review 8 studies)/meta-analysis	–	CT vs. MRI	Modern CT adequate for clearance; MRI detects ligamentous injuries rarely changing management; MRI reserved for select cases
Malhotra (29)	2018	USA	Retrospective cohort	1080 (712 negative CT with MRI)	CT (negative) vs. MRI	MRI positive in 20.9% after negative CT, but only ~6% unstable; CT NPV 98.5% for instability; management changed in 0.4%; MRI limited to persistent deficits
Quarrington (30)	2018	Australia	Retrospective cohort	226 patients	Radiographic features (CT/MRI/X-ray) vs. neurological status	C6–C7 most affected; dislocation, low GCS, canal occlusion, and cord compression predicted SCI; good-to-excellent reliability for radiographic measures

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Table 2. (*continued*)

Study (First Author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
Albaghdadi (31)	2019	USA	Retrospective cohort (NTDB)	32,107 patients	MRI utilization after CT vs. CT-only practice	MRI used in 9.9% overall; variation 0.5–68.7% across centers; more common in young, MVC, pedestrian injuries; adherence to CT-only guidance inconsistent
Baekgaard (32)	2019	USA and Denmark	Prospective cohort	113 (56 US; 57 Denmark)	CT-only vs. CT + clinical eval	Median collar removal time: 1042 min (US) vs. 49 min (DK); earlier clearance with post-CT clinical eval; prolonged immobilization despite CT-only protocol
Liebscher (33)	2019	USA and Brazil	Prospective cohort (multicenter, AAST)	2929 patients	Physical exam vs CT	No significant increase in missed injury with distracting injuries (10.4% vs. 12.6%); only one required surgery; negative PE sufficient in alert patients
Schoenfeld (34)	2019	USA	Narrative review 34 references)	–	CT vs. MRI vs. X-ray	CT is the primary screening tool; MRI adds sensitivity for soft-tissue injury but rarely changes management after negative CT; CT-only clearance reasonable in obtunded patients
Ravikanth (35)	2021	India	Comparative cohort	284 patients	Ultrasound vs. CT	Sensitivity 78.5%, specificity 98.4%, PPV 93.2%, NPV 92.8%; for unstable fragments sensitivity 100%; supports POCUS as adjunct in resource-limited settings
Chaudhary (36)	2022	USA	Retrospective cohort (multicenter, NTDB)	76,450 patients	MRI use pre- vs. post-2015 guideline	MRI use increased despite CT-only guidance; OR 1.77 post-2015; +10% per year trend (OR 1.10)

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Table 2. (*continued*)

Study (First Author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
Kania (37)	2022	USA	Retrospective cohort	751 patients	Physical exam vs. CT pan-scan	PE sensitivity 0.69; 50% had CT-detected injuries; CT-positive patients had higher ICU/OR utilization and mortality; CT preferred for geriatric trauma
Merza (38)	2022	Iraq	Prospective cohort	469 patients (59 with CSI)	CT and GCS vs. CSI presence	Strong correlation between TBI severity and CSI; CT and GCS both had high sensitivity/specificity; falls commonest mechanism
Williams (39)	2022	USA	Retrospective cohort (ED ≥ 65 years, ground-level falls)	1035 patients (CT in 683; 16 fractures)	Physical exam/history vs. CT	Neck pain, tenderness, AMS, and trauma above clavicles predicted fracture; combined sensitivity 100%, specificity 40%; absence of findings had NPV 99.3% for major fractures
Rutsch (40)	2023	Switz erland	Retrospective cohort	2321 patients	CT/MRI/X-ray/LODOX vs. clinical gold standard	CT sensitivity 88.6%, specificity 99%; MRI sensitivity 88.5%, specificity 96.9%; X-ray 36.4%, LODOX 5.3%; recommend MRI if symptomatic and CT negative

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Table 2. (*continued*)

Study (First Author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
Dion (41)	2024	Canada	Systematic review (6 studies)/meta-analysis	744 patients	CT alone vs. CT + MRI	6% missed injuries after negative CT; 7% required treatment; supports cautious use of MRI
Durler (42)	2024	USA	Retrospective cohort	501 blunt-trauma patients, GCS 15	Flexion-extension X-ray with MRI if incomplete	84.6% negative; 3.2% positive; 0.6% MRI-confirmed ligament injury (from incomplete F/E); no new neurologic deficits; MRI advised when F/E incomplete
Muhammad (43)	2024	Nigeria	Prospective cohort	143 patients	Cranio-cervical CT across GCS levels	CSI prevalence 11.2%; over half occurred with mild TBI; lower cervical levels most frequent; supports routine cranio-cervical CT regardless of GCS severity
Hahn Yong (44)	2025	Singapore	Systematic review (36 studies)/meta-analysis	6784 patients	CT vs. MRI	MRI found missed injuries in 17% and changed management in 4%; higher in pediatrics (32%) and alert patients

AAST = American Association for the Surgery of Trauma; AMS = Altered Mental Status; CCT = Canadian C-Spine Rule; CT = computed tomography; CSI = cervical spine injury; ED = emergency department; F/E = flexion-extension (radiographs); GCS = Glasgow Coma Scale; ICU = intensive care unit; LODOX, low-dose digital X-ray; LOL = loss of lordosis; MVC = motor vehicle collision; NEXUS = National Emergency X-radiography Utilization Study; NPV = negative predictive value; NNS = number needed to scan; NTDB = National Trauma Data Bank; PE = physical examination; POCUS = point-of-care ultrasound;PPV = positive predictive value; SCI = spinal cord injury; WTA = Western Trauma Association.

evidence to identify a single best option. One multicenter study measured collar-associated pressure injuries (54), suggesting that speeding up MRI would unlikely significantly reduce these events, reinforcing the importance of careful immobilization. Overall, pediatric data support clinical clearance and radiographs as initial steps, reserving CT for higher-risk cases, and using MRI for suspected ligamentous injury or ongoing neurological concerns (Table 3).

Discussion

Cervical spine clearance in trauma remains one of the most critical and debated steps in acute care, requiring a balance between avoiding missed unstable injuries and minimizing unnecessary immobilization or imaging. The evidence compiled in this systematic review, covering studies published from 2008 to 2025, supports the reliability of modern multidetector computed tomography (CT) with multiplanar reconstructions as the primary imaging modality for cervical spine clearance in both alert and obtunded trauma patients. Additionally, the findings reaffirm that meticulous clinical assessment—guided by validated instruments such as the NEXUS low-risk criteria and the Canadian C-Spine Rule—continues to be essential, particularly for alert, cooperative adults.

Adult Population

In adult trauma, CT has consistently demonstrated near-perfect diagnostic accuracy. Across large prospective cohorts and meta-analyses, the sensitivity and negative predictive value (NPV) of high-resolution CT for clinically significant or unstable cervical spine injury (CSI) reach 98–100% and over 99%, respectively (13,14,16,17,21,22,23,27–29). These findings support early collar removal after a normal CT scan, even in patients with unreliable examinations, such as those under the influence of intoxicants or with distracting injuries (21,27,33). MRI, although able to detect additional soft-tissue or ligamentous abnormalities, rarely altered clinical management—reported in 0.4–3% of cases (15,29,41). Therefore, its role now mainly includes specific situations, such as unexplained neurological deficits, ongoing pain despite a negative CT, or inconclusive radiologic findings (22,26,29,34,44).

Flexion–extension radiographs, once common, have shown limited diagnostic value and are frequently inadequate (14,24,42). In modern trauma protocols, they no longer play a significant role in clearance procedures. Additionally, resource-rich centers continue to debate MRI's added benefit, but evidence increasingly supports a "CT-first, MRI-when-needed" approach. The study by Fisher et al. (15) demonstrated that twenty-one MRI scans were required to find one clinically important additional lesion, while Tan et al. (17) showed 100% CT sensitivity and specificity for unstable injuries in a prospective cohort. Meta-analyses such as Veiga (28) and Dion (41) reached the same conclusion: modern CT alone is sufficient for clearance in most cases.

Clinical and operational factors also deserve attention. Prolonged immobilization following negative CT results is associated with discomfort, pressure ulcers, airway issues, and increased intracranial pressure (12). Implementing post-CT clinical reassessment protocols reduces collar time without compromising safety (32). In geriatric trauma patients, the lower reliability of physical examinations—due to frailty, osteopenia, and cognitive impairment—supports more liberal use of CT scans (37,39). Point-of-care ultrasound (POCUS) has shown potential as an adjunct in resource-limited settings but cannot replace CT because of its operator dependence and limited sensitivity for subtle fractures (35). Overall, these findings reinforce CT as the gold standard for adult cervical spine clearance, with MRI reserved for cases with exceptional diagnostic uncertainty.

Pediatric Population

In children, radiation exposure remains the main concern guiding imaging decisions. Pediatric studies (45,55) support structured clinical algorithms and selective imaging, focusing on physical examinations and plain radiography as first-line options. The review by Arbuthnot et al. (46) demonstrated 94.4% sensitivity and 99.9% NPV for clinical and radiographic clearance, with only one minor missed fracture. The "next-day" reassessment protocol proposed by Kavuri et al. (48) led to a significant reduction in CT use—from 90% to less than 30%—without missed injuries or longer hospital stays. Similar results were seen in Pennell et al. (49), where implementing standardized pediatric protocols cut down both CT and X-ray use while keeping diagnostic safety intact.

MRI maintains an important, though selective, role in pediatric clearance. Al-Sarheed et al. (47) reported ligamentous abnormalities on MRI after normal CT in 8% of cases, consistent with Hahn et al. (44), who found that MRI detected missed injuries in 32% of pediatric patients, though only a small percentage needed intervention. Scoring tools such as PEDSPINE I and II show limited sensitivity and variable specificity, which limits their standalone usefulness (51,52). Although uncommon, immobilization-related pressure injuries remain an important clinical issue: in a multicenter study by Melhado et al. (54), only four out of over 49,000 children developed collar-associated ulcers from prophylactic use, indicating that expedited MRI is unlikely to significantly

Table 3. Summary of Studies Assessing Cervical Spine Clearance in Pediatric Trauma patients. The Table Outlines Study Designs, Diagnostic Strategies, and Findings Regarding the Performance of Physical Examination, Radiographs, CT, and MRI in Identifying Clinically Significant Cervical Spine Injuries in Children.

Study (First author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
Moore (45)	2016	Australia	Retrospective cohort	47 patients	X-ray (CSS) and MRI; subset had CT	MRI identified 4 ligamentous injuries missed by radiographs and clarified 2 abnormal radiographs; authors conclude MRI has greater sensitivity/specificity than CSS and question routine CSS use
Arbuthnot (46)	2017	USA	Retrospective cohort	1023 patients	Physical exam + X-ray selective CT vs final diagnosis	Sensitivity 94.4%, NPV 99.9%; one missed minor fracture; most cleared without CT
Al-Sarheed (47)	2019	Saudi Arabia	Retrospective cohort	62 patients	CT vs. MRI and clinical assessment	CT sensitivity 84.8% and specificity 100%; 5 children had abnormal MRI after normal CT (mostly ligamentous injuries)
Kavuri (48)	2019	USA	Retrospective cohort	762 patients	Next-day physical exam + mandatory Spine consult vs. prior CT-heavy protocols	CT use fell 90%→42%→28.7% with no missed injuries; collar removal delayed (13–24 h) but no LOS increase
Pennell (49)	2020	USA	Retrospective cohort (pre- and post-protocol)	359 patients	Standardized protocol vs. pre-protocol usual practice	Clinical clearance increased (15.3%→43.2%); X-ray decreased (70.2%→55.0%); CT decreased (14.5%→5.4%); no missed injuries; estimated annual imaging charge reduction ~$396,476

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Table 3. (*continued*)

Study (First author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
King (50)	2022	USA	Retrospective cohort	652 patients	Clinical assessment in ED; imaging utilization recorded (no direct test comparison)	Neck pain reported by 13.8% (90/652); more common with acceleration/deceleration and MVC; more ED spine imaging and neurosurgery follow-up; no difference in concussion-clinic follow-up
Azad (51)	2024	USA	Retrospective cohort	88 patients	PEDSPINE I and II scores vs. MRI-confirmed CSI	PEDSPINE I: sensitivity 50%, NPV 93%; PEDSPINE II: specificity 91%, PPV 22%; missed mild ligamentous injuries on MRI
Capan (52)	2024	Turkey	Narrative review (5 studies from Cochrane)	21,379 patients	NEXUS, CCR, PEDSPINE, PECARN/NICE derivatives vs. reference standards	High sensitivity but low specificity; insufficient evidence to identify best tool; better studies needed

(*continued on next page*)

Table 3. *(continued)*

Study (First author)	Year	Country	Design	Sample (n)	Index vs. Comparator (Physical Exam/CT/MRI/X-ray/Ultrasound)	Findings
Duncan (53)	2024	USA	Retrospective cohort	289 patients	CT vs. MRI and clinical outcomes	CT positive in 13.8%; no additional MRI findings; supports collar removal with negative CT
Melhado (54)	2024	USA	Retrospective cohort (multicenter)	49,218 patients	Cervical collars/braces (therapeutic or prophylactic); no comparator arm (descriptive)	Median time to HAPI diagnosis 11 days; 78% occurred in children requiring immobilization for cervical injuries; only 4 HAPI occurred with prophylactic collars; expediting MRI unlikely to meaningfully reduce HAPI
Starr (55)	2025	USA	Retrospective cohort	2081 patients (negative X-rays)	Screening X-ray with/without additional CT/MRI	Sensitivity 100% for clinically significant injuries; 95% cleared without further imaging; additional imaging commonly for pain (48%), GCS $\leq$14 (44%), paresthesias (8%)

CCR = Canadian C-Spine Rule; CSS = cervical spine series (plain radiographs); CSI = cervical spine injury; CT = computed tomography; ED = emergency department; GCS = Glascow Coma Scale; HAPI = hospital-acquired pressury injury; LOS = length of stay; MRI = magnetic resonance imaging; MVC = motor vehicle collision; NEXUS = National Emergency X-Radiography Utilization Study; NPV = negative predictive value; PECARN = Pediatric Emergency Care Applied Research Network; PEDSPINE = Pediatric Cervical Spine Injury Score; PPV = positivie predictive value.

reduce this risk. Overall, pediatric clearance should emphasize clinical examination and judicious radiography, reserving CT and MRI for high-risk or neurologically unreliable cases.

Practical Implications

Across all age groups, timely cervical spine clearance is a determinant of both safety and efficiency. While immobilization protects the spine from secondary neurologic injury (“second hit,” such as raised intracranial pressure, spinal cord compromise, or peripheral nerve injury related to prolonged immobilization), unnecessary collar retention can lead to more complications and longer hospital stays (12,32). In institutions with widespread access to CT, early clearance protocols—supported by thorough clinical reassessment—have proven to be both safe and cost-effective. In resource-limited settings, POCUS may be used as an adjunct, but not a substitute, for CT (35).

This synthesis supports a tiered approach:

1. *Clinical clearance* for alert, asymptomatic adults meeting CCR criteria.
2. *CT-based clearance* for patients with unreliable examinations or risk factors such as intoxication or advanced age.
3. *MRI-targeted clearance* for unresolved neurologic symptoms, ambiguous CT findings, or pediatric ligamentous concerns.

In this hierarchy, CT with multiplanar reconstructions serves as the de facto gold standard—the imaging modality against which others are evaluated—because of its unmatched reliability, speed, and accessibility.

Limitations and Future Directions

Although the present synthesis bases its findings on extensive and recent literature, variability in study design, inclusion criteria, and diagnostic standards introduces inherent heterogeneity. Differences in imaging protocols, scanner resolution, and radiologist expertise may influence performance estimates, especially in older studies that predate modern CT technology. The evidence for pediatric and geriatric groups is relatively limited, reflecting ethical and practical challenges to large-scale prospective validation. Additionally, institutional differences in the use of MRI after a negative CT underscore the need for unified, evidence-based guidelines that optimize resource use without compromising diagnostic safety. Future research should move beyond simple imaging comparisons toward integrated, data-driven approaches that combine clinical scoring, advanced imaging analytics, and artificial intelligence (AI)-assisted triage models. Multicenter prospective studies, particularly focusing on pediatric and elderly populations, are crucial to establishing a global consensus on safe, effective, and patient-centered cervical spine clearance.

Conclusion

The combined evidence over the past two decades establishes high-quality CT as the essential tool for cervical spine clearance in trauma. Clinical assessment remains pivotal in risk stratification and guiding selective imaging. MRI should be employed judiciously, tailored to cases of clinical-radiologic discordance or persistent neurologic deficits. In pediatric trauma, the balance between diagnostic accuracy and radiation exposure leads to a conservative, protocol-based approach that emphasizes clinical examination and plain radiography. Ultimately, adopting structured, evidence-based clearance algorithms reduces missed injuries, speeds up care, and improves patient safety throughout trauma management.

Ethics approval

This study is a literature review based entirely on previously published data and does not involve new human participants, animals, or patient information.

Consent to participate

This study was based exclusively on previously published studies and did not require informed consent from patients, as no new human or critical data were collected.

Consent to publish

The author is the owner of the illustrations and gives consent for publication in this journal.

Data availability

All data underlying this study are derived from previously published articles available in the PubMed database. No new datasets were generated or analyzed in this review. References to all included are provided in the manuscript.

Declaration of competing interest

The authors declare no conflicts of interest concerning the materials or methods used in this study or the findings specified in this paper.

CRediT authorship contribution statement

Helbert de Oliveira Manduca Palmiero: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eberval Gadelha Figueiredo:** Writing – review & editing, Supervision.

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Article Summary

1. Why is this topic important?

Missed unstable cervical injuries can cause catastrophic neurologic harm, while unnecessary collars and imaging increase complications, ED length of stay, and costs.

2. What does this review attempt to show?

It synthesizes current adult and pediatric evidence to define safe, efficient, and evidence-based pathways for cervical spine clearance using clinical rules and selective imaging.

3. What are the key findings?

- In adults, high-quality CT has ~98–100% sensitivity and >99% NPV for clinically significant injury; routine post-CT MRI seldom alters management.
- Flexion–extension radiography is low-yield and largely de-emphasized.
- In children, structured algorithms using plain radiographs and examinations safely reduce CT use, with MRI reserved for ligamentous concerns or persistent symptoms.

4. How is patient care impacted?

- Earlier and safer collar removal after a normal CT reduces complications and length of stay.
- Radiation exposure in children is minimized through protocolized, selective imaging.
- Standardized, tiered algorithms streamline workflow and resource use without compromising safety.