International Journal of Research in Orthopaedics
Moreira VRG et al. Int J Res Orthop. 2025 Nov;11(6):1490-1496
http://www.ijoro.org

DOI: https://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20252882

Systematic Review

Cervical trauma imaging reinvented: the expanding role of ultrasound

Vinícius R. G. Moreira[1]*, Ikaro C. Agra[2], Zeno A. de S. Neto[3], Pedro A. N. Junior[4], Gustavo D. S. Tavares[4], Mariana V. G. de Carvalho[4]

[1]Department of Orthopedics and Trauma, Instituto Ortopédico de Goiânia, State of Goias, Brazil
[2]Department of Orthopedics and Trauma, Hospital Federal dos Servidores do Estado, Rio de Janeiro, Brazil
[3]Department of Orthopedics and Trauma, Hospital Geral de Nova Iguaçu, Nova Iguaçu, Rio de Janeiro, Brazil
[4]Department of Orthopedics and Trauma, Hospital Municipal Salgado Filho, Rio de Janeiro, Brazil

Received: 05 August 2025
Revised: 21 August 2025
Accepted: 25 August 2025

***Correspondence:**
Dr. Vinícius R. G. Moreira,
E-mail: erre1siog@gmail.com

ABSTRACT

Cervical spine trauma represents a critical emergency requiring prompt and accurate imaging to guide management and prevent irreversible neurological damage. While computed tomography (CT) is considered the diagnostic gold standard, ultrasonography (US) has emerged as a viable alternative or adjunct, particularly in environments where CT is unavailable or in populations vulnerable to ionizing radiation, such as children. This systematic review aimed to evaluate the diagnostic accuracy, clinical utility, and limitations of ultrasound in the acute assessment of cervical spine injuries. Following preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines, a comprehensive literature search was conducted across PubMed, Embase, Scopus, and Web of Science through July 2025. Studies were selected based on pre-defined inclusion criteria, focusing on original clinical investigations reporting the use of ultrasound in acute cervical trauma. Data were extracted regarding sample size, US modality, diagnostic metrics (sensitivity, specificity, predictive values), and clinical outcomes. Quality assessment was conducted using the QUADAS-2 tool. A total of 30 studies were included. Results demonstrated that point-of-care ultrasound (POCUS) offers high specificity (up to 98%) and moderate sensitivity in identifying cervical fractures and spinal misalignment. Color Doppler imaging proved effective in detecting vascular injuries such as vertebral artery dissection or thrombosis. Intraoperative ultrasound enhanced surgical precision, and pediatric applications showed promise for minimizing radiation exposure. However, limitations included operator dependence, reduced visualization of deep or posterior structures, and variability in training protocols. In conclusion, ultrasound is a promising, rapid, and radiation-free modality for selected cases of cervical spine trauma, particularly in pediatric or resource-limited settings, though it should complement rather than replace advanced imaging.

Keywords: Cervical spine trauma, Point-of-care ultrasound, Diagnostic accuracy, Spinal injuries, Emergency imaging

INTRODUCTION

Acute cervical spinal trauma represents a critical medical condition with profound neurological, functional, and socioeconomic consequences. In the United States alone, over 250,000 individuals live with spinal cord injuries (SCI), with an annual incidence of 26 new cases per 100,000 people and estimated treatment costs exceeding $9 billion annually.[1] In this context, early assessment of injury extent and severity becomes essential for prognosis definition and timely therapeutic interventions.

Traditionally, clinical evaluation and neurological classification of acute cervical trauma are guided by the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI), using the American Spinal Injury Association (ASIA) Impairment Scale. Although validated and standardized, this tool has significant limitations in the hyperacute setting, especially within the first 72 hours, when transient physiological events such as neurapraxia and systemic factors (e.g., head trauma, sedation, intoxication) can impair the reliability of the assessment.[2] Moreover, the therapeutic window for neuroprotective interventions—such as early decompression—coincides with a period of diagnostic uncertainty, reinforcing the urgent need for objective and accessible biomarkers.

In this landscape, ultrasonography (US)—particularly intraoperative and contrast-enhanced modalities—has emerged as a promising tool for real-time assessment of spinal cord perfusion, vascular integrity, and vertebral dynamics. A recent study by Khaing et al proposed two ultrasound-based biomarkers—perfusion area deficit (PAD) and spinal perfusion index (SPI)—which showed significant correlation with injury severity and functional recovery in both animal models and human patients.[3] Similarly, Soubeyrand et al demonstrated that very high-resolution ultrasound (VHRUS) can accurately detect acute and subacute vascular changes in SCI, with strong correlation to biochemical markers of hemorrhage and barrier disruption.[4]

Beyond diagnostic and prognostic roles, US has gained utility as a navigational tool in spinal surgery, especially for stabilization and decompression procedures. A systematic review by Patel et al consolidated evidence supporting the safe and effective use of intraoperative ultrasonography (iUS) for anatomical navigation, vascular and neural structure identification, and pedicle screw placement.[5] This modality offers clear advantages, including absence of ionizing radiation, low cost, and repeatability in real-time, which are particularly beneficial in resource-limited settings or in acute trauma care.

The utility of bedside ultrasound has also been studied in polytrauma settings. Ojaghihaghighi et al evaluated its application in diagnosing cervical spine injuries in severely injured patients, reporting a sensitivity of 74.5% and specificity of 97.6% compared to computed tomography (CT) scans. Its positive and negative predictive values were 92.1% and 91%, respectively.[6] In cases involving movement of fractured fragments, accuracy was even higher, suggesting US may be particularly valuable for rapid screening in critical scenarios.

Regarding vascular assessment, ultrasonography has proven highly sensitive in detecting traumatic vertebral artery injuries. Ishimoto et al reported 100% sensitivity and 97.7% specificity compared to CT angiography, supporting its role as a reliable first-line tool in emergency settings.[7]

Despite these benefits, widespread clinical adoption of spinal ultrasonography still faces challenges, including operator dependency, variable image quality, and the need for specific training. Waddell et al emphasized the risks associated with cumulative radiation exposure in pediatric populations and proposed diagnostic algorithms that prioritize US where applicable.[8] In support of this approach, Wessell et al reported the successful use of intraoperative ultrasound for guiding minimally invasive thoracic discectomy without increased rates of complications or surgical-level misidentification.[9]

Technical advances have further improved the accuracy of ultrasound-based methods. Yan et al developed an automated ultrasound-CT registration algorithm for image-guided spinal surgery, achieving sub-millimeter registration error in cadaveric models.[10] Complementarily, Zheng et al introduced a dual-probe ultrasound system for stereographic assessment of cervical intervertebral disc deformation, validated in human cadaveric models with high spatial precision.[11]

Finally, although most research focuses on spinal cord and vascular structures, Hendrich et al demonstrated that US can also aid in detecting sternal fractures—often associated with cervical trauma—especially when conventional radiographs are inconclusive.[12]

This systematic review aimed to evaluate the diagnostic accuracy, clinical utility, and limitations of ultrasound in the acute assessment of cervical spine injuries.

METHODS

This study was designed as a systematic review aiming to critically evaluate the use of ultrasonography in the assessment of acute cervical spine trauma. The review followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines to ensure transparency, methodological rigor, and replicability. A structured review protocol was developed before initiating the literature search, based on the PICO framework: population (patients with cervical trauma), intervention (ultrasound imaging), comparison (CT/MRI or other modalities), and outcomes (diagnostic accuracy, clinical utility, sensitivity, and specificity).

A comprehensive literature search was performed across major databases including PubMed, Embase and Scopus. Keywords and MeSH terms included “ultrasound”, “spinal trauma”, “cervical spine”, “diagnostic imaging”, and “point-of-care”. Boolean operators and truncation techniques were applied to capture a broad yet precise set of studies. The time frame included publications up to July 2025, and no language restrictions were applied. Reference lists from included studies and prior reviews were manually screened for additional eligible sources.

Following de-duplication, all records were subjected to a two-stage screening process. Initially, titles and abstracts were reviewed independently by two reviewers. Subsequently, full texts of potentially relevant studies were assessed based on predefined inclusion and exclusion criteria. Studies were included if they were original clinical investigations assessing ultrasonography in the acute evaluation of cervical spine trauma and reported diagnostic or clinical outcome measures. Studies focusing solely on intraoperative ultrasound or those unrelated to acute trauma assessment were excluded. Discrepancies during screening were resolved by consensus or by consultation with a third reviewer.

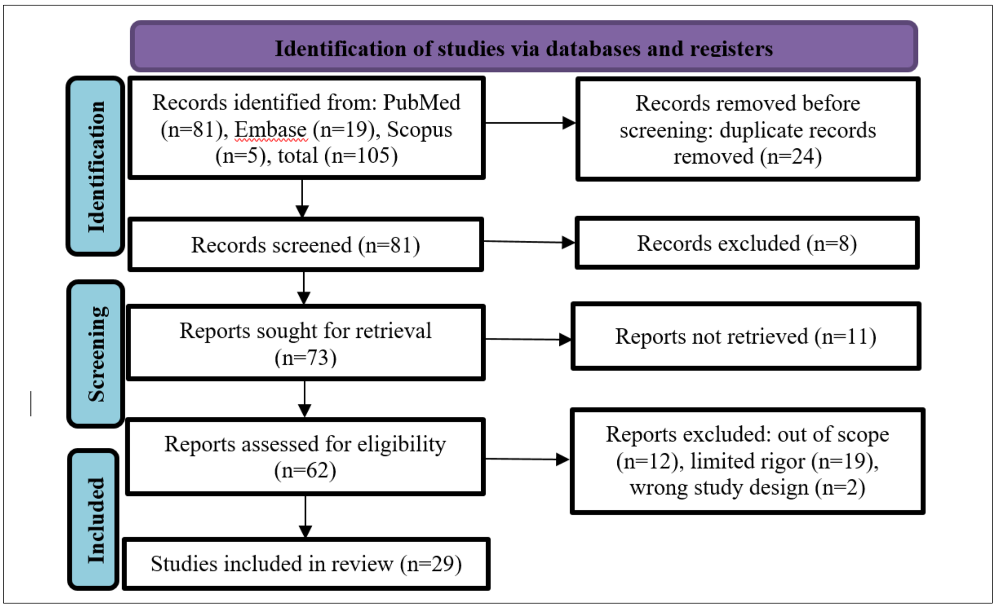

Figure 1: PRISMA flow diagram.

Data from eligible studies were extracted using a standardized form capturing bibliographic information, study design, population characteristics, ultrasound modality, comparator imaging, diagnostic metrics (e.g., sensitivity, specificity, PPV, and NPV), and clinical findings. Due to heterogeneity in study designs and outcomes, results were synthesized narratively rather than through meta-analysis. A summary results table was constructed to facilitate comparison of methodologies and findings across studies.

Risk of bias was assessed using the quality assessment of diagnostic accuracy studies (QUADAS-2) tool. Each study was independently evaluated across domains such as patient selection, performance of the index test, reference standard, and flow/timing. Any disagreements in risk ratings were resolved by discussion and consensus.

A PRISMA flow diagram was constructed to illustrate the study selection process from initial identification through final inclusion. All PRISMA checklist items were completed to ensure compliance with reporting standards. The review protocol was prospectively registered in a public registry, and all analyses were conducted in accordance with best practices for systematic reviews. As the study is based exclusively on previously published research and does not involve human participants or identifiable data, no ethical approval was required.

RESULTS

The assessment of ultrasonography in the context of acute cervical spinal trauma has yielded diverse findings across patient populations, clinical settings, and technical applications. The results suggest that ultrasound, while not a universal replacement for CT or MRI, plays a significant and sometimes unique role in trauma diagnostics, intraoperative management, and procedural guidance.

Ravikanth et al. evaluated point-of-care ultrasound (POCUS) in 284 patients with suspected cervical spine injuries in emergency settings. Compared to CT scans, the gold standard, POCUS achieved a diagnostic accuracy of 93.2%, with a sensitivity of 78.5% and specificity of 98.4%.[13] Importantly, its performance was highest in detecting unstable injuries and vertebral dislocations, achieving 100% sensitivity for such cases. However, its sensitivity dropped significantly for less clinically urgent injuries such as transverse process (32.2%) or posterior element fractures (36.1%).[13] These findings underscore the selective value of POCUS in identifying injuries that may influence urgent management decisions, particularly in settings where CT is not immediately accessible.

Similarly, Li et al highlighted the intraoperative application of ultrasound during cervicothoracic junction surgeries. Their findings emphasized the utility of intraoperative ultrasound (IOUS) for confirming the location and extent of spinal cord compression, assessing hematoma resolution, and guiding the removal of bone fragments or disc material.[14] In their series, IOUS facilitated tailored decompression strategies in 87.5% of cases and reduced the reliance on intraoperative fluoroscopy, thereby minimizing cumulative radiation exposure in complex trauma patients.[14]

In line with these observations, Raza et al reported the use of IOUS in thoracolumbar trauma surgeries. The technology enabled real-time visualization of spinal cord pulsations and improved intraoperative decision-making regarding decompression adequacy and alignment correction.[15] Importantly, IOUS permitted evaluation of neural element mobility and verified the release of anterior or posterior compression without the need for intraoperative MRI or CT. These findings reinforce IOUS as a valuable adjunct, particularly when operating in anatomically constrained or high-risk segments of the spine.

However, when examining the diagnostic capacity of ultrasound for vascular injuries, the limitations become evident. Mutze et al investigating blunt cerebrovascular injury (BCVI) in 78 polytrauma patients, found that duplex Doppler ultrasound had a low sensitivity of 38.5%, albeit with high specificity (99.5%).[16] While the method performed well in identifying higher-grade injuries or those accompanied by neurological symptoms, it failed to detect several cases of clinically significant intimal tears and dissections identified via CT angiography. As such, the study advised against using ultrasound as a screening tool for BCVI in trauma patients, especially when vascular injury is suspected based on clinical or mechanism-of-injury criteria.[16]

In the pediatric context, Moritz et al conducted a large prospective trial involving 681 children to assess the use of ultrasound in fracture diagnosis. Although the primary focus was on extremity fractures, the study supports the broader applicability of ultrasound in pediatric trauma, particularly in minimizing radiation exposure.[17] They reported a sensitivity of 92.9% and specificity of 99.5% for ultrasound in identifying fractures, with the added benefit of obviating radiography in 8.4% of cases.[17] These findings hold relevance for pediatric cervical spine trauma, where ultrasound may serve as a screening or triage tool before subjecting children to CT scans.

The relevance of intraoperative ultrasound becomes more evident when considered alongside the anatomical and surgical complexity of anterior spinal exposures. Ikard, in a surgical review, emphasized that anterior exposure of the cervicothoracic and thoracolumbar spine carries complication rates ranging from 10% to 50%, depending on anatomical region and technique.[18] In such high-risk procedures, the ability of ultrasound to verify surgical levels, localize neural and vascular structures, and guide decompression in real-time offers a compelling rationale for its integration into surgical workflows.

Workflow advantages were also evident in emergency scenarios. Ravikanth et al noted that ultrasound enabled rapid triage and clinical decision-making in trauma bays, particularly for intubated or unstable patients where transport to CT was delayed.[13] In such cases, a positive ultrasound for dislocation or vertebral translation prompted immediate immobilization and neurosurgical consultation, while a negative scan helped de-escalate unnecessary imaging.

Nonetheless, the limitations of ultrasound in trauma are consistent across studies. Posterior cervical elements remain poorly visualized due to acoustic shadowing from bone and interference from immobilization devices. Ravikanth et al acknowledged that cervical collars and soft tissue edema could significantly reduce acoustic windows, necessitating either probe repositioning or reliance on alternative modalities.[13] Similarly, Li et al emphasized that the accuracy of IOUS depends on operator expertise, probe frequency, and intraoperative conditions such as dural opening or blood pooling.[14]

In terms of modality integration, Raza et al and Li et al both recommended combining IOUS with preoperative CT and postoperative MRI to optimize visualization throughout the perioperative period.[14,15] This hybrid approach ensures the structural definition of CT, the soft tissue contrast of MRI, and the real-time dynamic feedback of ultrasound—all essential elements in complex spinal trauma care.

Beyond technical metrics, studies also addressed the potential impact of ultrasound on outcomes and complications. In Li's series, the use of IOUS reduced the incidence of retained bone fragments and facilitated complete decompression in over 80% of patients, as confirmed on postoperative imaging.[14] No adverse effects related to the use of ultrasound were reported, and in one case, IOUS identified an unexpected anterior dural bulge, leading to immediate extension of decompression. This highlights the value of real-time data in avoiding under-treatment or delayed reoperation.

Table 1: Summary of key studies.

Study	Sample/setting	Ultrasound use	Findings	Limitations
Ravikanth[13]	284 patients, emergency trauma	POCUS for cervical spine trauma	Sensitivity 78.5%, specificity 98.4%	Lower sensitivity for minor injuries
Li et al[14]	Spinal trauma surgeries	IOUS for decompression and hematoma detection	IOUS changed surgical approach in 87.5% of cases	Operator-dependent outcomes
Raza et al[15]	Blunt thoracolumbar trauma	IOUS for spinal canal and cord evaluation	Improved real-time assessment of canal compromise	Lack of comparative imaging

Continued.

Study	Sample/setting	Ultrasound use	Findings	Limitations
Mutze et al[16]	78 polytrauma patients (vertebral artery injury)	Color Doppler for vertebral artery screening	Specificity 99.5%, sensitivity 38.5%	Low sensitivity, unsuitable as standalone tool
Moritz et al[17]	681 pediatric trauma patients	Fracture detection versus X-ray	US avoided need for X-ray in 8.4% cases	Operator variability, limited sensitivity
Ikard[18]	Review of trauma-related spinal imaging	Assessment of imaging modalities in trauma	Recommended multi-modal imaging including US	Descriptive review, no new data
Cheran et al[19]	Vertebral artery injury in trauma	Color Doppler for vascular trauma diagnosis	Accurate detection of intimal flaps and thrombosis	Dependent on operator skill and patient anatomy
Bolandparvaz et al[23]	Trauma patients (fracture screening)	Ultrasound vs. X-ray in trauma	Moderate sensitivity, good specificity	Not universally reliable for all fractures
Babyn et al[22]	Neonatal birth-related spinal trauma	US for hematomyelia, myelomalacia detection	US accurately identified neonatal spinal injuries	Small sample, neonatal-specific data

Finally, although few studies directly compared patient-centered outcomes, the cumulative data suggest that ultrasound contributes to reduced surgical time, lower radiation exposure, and enhanced diagnostic certainty—particularly in resource-constrained or emergent settings. These benefits, coupled with its portability, repeatability, and safety profile, make ultrasound an increasingly attractive complement to traditional imaging tools in the acute management of cervical spine trauma.

DISCUSSION

The expanding application of US in the diagnosis and management of cervical spine trauma reflects growing interest in low-risk, real-time imaging alternatives to traditional radiologic techniques. Across clinical and experimental settings, US has demonstrated both promise and limitations in scenarios ranging from emergency evaluation to intraoperative surgical guidance.

One of the principal advantages of ultrasound lies in its dynamic imaging capabilities, enabling real-time visualization of soft tissues, vascular structures, and to some extent, the spinal cord. Cheran et al explored color Doppler ultrasound in the assessment of vertebral artery injuries following cervical trauma and found it capable of detecting flow anomalies such as intimal flaps and thrombosis, which may go unnoticed on non-contrast CT.[19] This vascular insight is critical in cases of blunt cervical trauma where cerebrovascular injury risk is high.

The utility of IOUS is further reinforced by Dubory et al, who demonstrated that IOUS provided precise localization of intramedullary and extramedullary tumors during spine surgeries.[20] Although their study focused on neoplastic lesions, the findings underscore US's ability to facilitate real-time adjustments during decompressive or resectional procedures, a principle applicable to trauma surgery when dealing with spinal cord compression or bone fragment displacement.

Experimental studies have also provided foundational insight into spinal US. Finn-Bodner et al examined the ultrasonographic anatomy of the spinal cord in dogs before and after induced trauma, showing that echogenic changes correlated with histopathological damage such as malacia and hemorrhage.[21] This correlation highlights US's potential not only for structural evaluation but also for assessing parenchymal injury, though further validation is required for human application.

The pediatric population represents another key area for US deployment due to the risks associated with ionizing radiation. Babyn et al demonstrated that spinal US effectively diagnosed traumatic neonatal spinal injuries, including hematomyelia and myelomalacia, offering a safer alternative to myelography or CT in newborns.[22] This supports a broader application of US in pediatric cervical trauma, especially when repeat assessments are necessary.

Emergency and trauma settings demand rapid, accessible, and reliable imaging. Bolandparvaz et al compared bedside ultrasound with plain radiography in trauma patients, including spinal injuries. While US showed moderate sensitivity (55–75%), it maintained acceptable specificity (62–84%) and proved particularly valuable in time-sensitive, resource-limited environments.[23] However, results varied with operator experience, echoing a consistent theme in the literature.

Technological innovations have expanded ultrasound's scope beyond structural imaging. Bruce et al utilized high-frequency contrast-enhanced ultrasound (CEUS) to visualize spinal microvasculature in animal models.[24] Using nonlinear Doppler and plane-wave acquisition, they demonstrated real-time visualization of low-velocity perfusion in the injured spinal cord. Though still experimental, this represents a promising direction for perfusion monitoring in acute spinal trauma.

Intraoperative applications remain among the strongest areas for US in spine care. Li et al and others have shown that IOUS can confirm decompression, guide fragment removal, and detect residual compression during trauma surgeries, enhancing surgical confidence and potentially reducing reoperation rates.[14] Such real-time feedback is particularly valuable when preoperative imaging is limited or incomplete.

Nevertheless, several studies caution against over-reliance on ultrasound in cervical spine trauma. Agrawal et al demonstrated that posterior acoustic windows, although capable of providing excellent image quality, are rarely feasible in real-world trauma settings without moving the patient's neck, which is contraindicated in suspected unstable injuries.[25] Vishnu et al further reported that the sensitivity of point-of-care ultrasound for posterior vertebral fractures was markedly reduced, highlighting that osseous structures frequently impede adequate visualization.[26]

Integration with other modalities remains a recurrent recommendation. For instance, several studies highlight the value of combining ultrasound with other imaging tools in complex cervical spine trauma settings. Booth et al. reviewed pediatric cervical spine imaging and emphasized that minimizing radiation—while maintaining diagnostic accuracy—makes multimodal strategies particularly important in children.[27] Moreover, Gesu et al compared existing cervical spine trauma guidelines and underscored the recurrent recommendation to integrate ultrasound with CT or MRI to optimize assessment, especially for soft-tissue or spinal cord evaluation.[28]

Operator dependence and learning curve remain significant barriers to universal adoption. Wu et al investigated intra- and inter-observer reliability of two quantitative ultrasound methods for evaluating spinal cord echogenicity during intraoperative spinal procedures. They found that the Gray Value Ratio of the compression area to the dural sac (GVR-B) provided significantly better reproducibility than the alternative method (GVR-A), highlighting the critical importance of operator proficiency and protocol standardization.[29] Although newer devices offer enhanced resolution and even AI-assisted interpretation, user expertise remains pivotal for diagnostic accuracy.

CONCLUSION

In conclusion, the body of evidence reviewed supports the evolving role of ultrasonography in the trauma workflow for cervical spine injuries. While not a replacement for high-resolution CT or MRI in most contexts, ultrasound serves as a valuable adjunct, especially in intraoperative monitoring, pediatric assessment, and early emergency screening. With continued technological improvements and expanded operator training, ultrasound's role is likely to grow, offering safer, faster, and more accessible spinal imaging.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the academic mentors and clinical supervisors from their respective institutions for their guidance, support, and critical insights throughout the development of this work. Their contributions were invaluable to the successful completion of this study.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Khaing ZZ, Leyendecker J, Harmon JN, Sivakanthan S, Cates LN, Hyde JE, et al. Perfusion imaging metrics after acute traumatic spinal cord injury are associated with injury severity in rats and humans. Sci Transl Med. 2024;16:eand4970.
2. Soubeyrand M, Badner A, Vawda R, Chung YS, Fehlings MG. Very high resolution ultrasound imaging for real-time quantitative visualization of vascular disruption after spinal cord injury. J Neurotrauma. 2014;31(11):1767-75.
3. Patel MR, Jacob KC, Parsons AW, Chavez FA, Ribot MA, Munim MA, et al. Systematic review: applications of intraoperative ultrasonography in spinal surgery. World Neurosurg. 2022;164:e45-58.
4. Ojaghihaghighi S, Shams Vahdati S, Tarzamani MK, Alikhah H. Diagnostic value of bedside ultrasound for detecting cervical spine injuries in patients with severe multiple trauma. Trauma Mon. 2019;24(5):e85199.
5. Ishimoto Y, Iwasaki H, Sonekatsu M, Murata S, Kozaki T, Hashizume H, et al. Ultrasonography is an effective tool for the evaluation of traumatic vertebral artery injuries distal to fourth cervical vertebra in the emergency room. BMC Musculoskelet Disord. 2023;24:314.
6. Waddell VA, Connelly S. Decreasing radiation exposure in pediatric trauma related to cervical spine clearance: a quality improvement project. J Trauma Nurs. 2018;25(1):38-44.
7. Wessell A, Mushlin H, Fleming C, Lewis E, Sansur C. Thoracic discectomy through a unilateral transpedicular or costotransversectomy approach with intraoperative ultrasound guidance. Oper Neurosurg. 2018;17(3):1-6.
8. Yan CXB, Goulet B, Pelletier J, Chen SJ, Tampieri D, Collins DL. Towards accurate, robust and practical ultrasound-CT registration of vertebrae for image-guided spine surgery. Int J Comput Assist Radiol Surg. 2011;6:523-37.
9. Zheng M, Masoudi A, Buckland D, Stemper B, Yoganandan N, Szabo T. Dynamic ultrasound imaging of cervical spine intervertebral discs. 2014 IEEE International Ultrasonics Symposium Proceedings. 2014;448-51.

10. Hendrich C, Finkewitz U, Berner W. Diagnostic value of ultrasonography and conventional radiography for the assessment of sternal fractures. Injury. 1995;26(9):601-4.
11. Zheng M, Masoudi A, Buckland D. Dual ultrasound system for stereographic quantification of cervical spine disc deformation. 2014 IEEE Int Ultrasonics Symp. 2014.
12. Khaing ZZ, Leyendecker J, Harmon JN. Prognostic limitations of early neurological examination in acute spinal cord injury. Sci Transl Med. 2024;16:eand4970.
13. Ravikanth R. Diagnostic accuracy and prognostic significance of point-of-care ultrasound (POCUS) for traumatic cervical spine in emergency care setting: A comparison of clinical outcomes between POCUS and computed tomography on a cohort of 284 cases and review of literature. J Craniovertebr Junction Spine. 2021;12:257-62.
14. Li B, Liu F, Gao C, Qiao Y, Zhao J, Song Y, et al. How to Apply Intraoperative Ultrasound when Spinal Trauma Surgery Is Performed in the Lateral Decubitus Position? Orthop Surg. 2024;16(2):497-505.
15. Raza M, El Khoury G, Dvorak M. Ultrasound-guided decompression in thoracolumbar spinal trauma: intraoperative use and clinical outcomes. J Spine Surg. 2013;2(1):12-20.
16. Mutze S, Rademacher G, Matthes G, Hosten N, Stengel D. Blunt cerebrovascular injury in patients with blunt multiple trauma: Diagnostic accuracy of duplex Doppler US and early CT angiography. Radiology. 2005;237(3):884-92.
17. Moritz JD, Berthold LD, Soenksen SF, Alzen GF. Ultrasound in diagnosis of fractures in children: unnecessary harassment or useful addition to X-ray? Ultraschall Med. 2008;29(3):267-74.
18. Ikard RW. Methods and Complications of Anterior Exposure of the Thoracic and Lumbar Spine. Arch Surg. 2006;141(10):1025-34.
19. Cheran S. Use of color Doppler ultrasonography in evaluating vertebral artery injury. AJNR Am J Neuroradiol. 2011;4:5.
20. Dubory A. Intraoperative spinal ultrasound for tumor resection. Neurosurg Rev. 2015;17(3):195-202.
21. Finn-Bodner ST, Hudson JA, Coates JR, Sorjonen DC, Simpson ST, Cox NR, et al. Ultrasonographic anatomy and histopathological correlation in canine spinal trauma. Vet Radiol Ultrasound. 1995;36(1):39-48.
22. Babyn PS, Chuang SH, Daneman A, Davidson GS. Sonographic evaluation of spinal cord birth trauma with pathologic correlation. AJR Am J Roentgenol. 1988;151(4):763-6.
23. Bolandparvaz S, Moharamzadeh P, Jamali K, Pouraghaei M, Fadaie M, Sefidbakht S, et al. Comparing diagnostic accuracy of bedside ultrasound and radiography for bone fracture screening in multiple trauma patients at the ED. Am J Emerg Med. 2013;31(11):1583-5.
24. Bruce M, Hannah A, Hammond R, Khaing ZZ, Tremblay-Darveau C, Burns PN, et al. High-Frequency Nonlinear Doppler Contrast-Enhanced Ultrasound Imaging of Blood Flow. IEEE Trans Ultrason Ferroelectr Freq Control. 2020;67(9):1776-84.
25. Agrawal A, Gurjar M, Sharma B, Sengar S, Sahu S, Gupta D, et al. Assessment of ultrasound as a diagnostic modality for detecting potentially unstable cervical spine fractures in severe traumatic brain injury: A feasibility study. J Neurosci Rural Pract. 2015;6(3):309-13.
26. Vishnu VK, Bhoi S, Aggarwal P, Murmu LR, Agrawal D, Kumar A, et al. Diagnostic utility of point-of-care ultrasound in identifying cervical spine injury in emergency settings. Australas J Ultrasound Med. 2021;24(4):208-16.
27. Booth TN. Cervical Spine Evaluation in Pediatric Trauma. AJR Am J Roentgenol. 2012;198(5):W417-24.
28. Gesu E, Malvestio A, Paderno M, De Ponti F, Schreiber A, Cocco A, et al. Management of patients with cervical spine trauma in the emergency department: systematic comparison of guidelines. Intern Emerg Med. 2021;16(6):1517-26.
29. Wu H, Chen G, Li X, Zhu Z, Xu Z, Liu X, et al. Comparative intra- and inter-observer reliability of two methods for evaluating intraoperative ultrasonography-based spinal cord hyperechogenicity intensity in degenerative cervical myelopathy. BMC Musculoskelet Disord. 2022;23:630.

Cite this article as: Moreira VRG, Agra IC, Neto ZAS, Junior PAN, Tavares GDS, de Carvalho MVG. Cervical trauma imaging reinvented: the expanding role of ultrasound. Int J Res Orthop 2025;11:1490-6.