CRITICAL ANALYSIS OF IMAGING TECHNIQUES FOR EVALUATING TRAUMATIC SPINE INJURIES.

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Abstract

Spine injuries developing through a traumatic process represent a problematic and crucial diagnostic and medical care dilemma that should be diagnosed correctly and done rapidly to rule out proper treatment decisions. Imaging procedures are of paramount importance in appraising the intensity and degree of spinal injuries, which are mainly to diagnose them, prepare a treatment plan, and predict the result. This essay outlines the types of imaging techniques that are primarily applied in evaluating spine injuries caused by trauma, including X-rays, CT scans, MRIs, and advanced imaging methods. The strengths and shortcomings of the used imaging are pointed out, and the applicability of each in various client cases is highlighted. Also, guidelines for selecting the best imaging techniques and accuracy for diagnosis are proposed to help the management of traumatic spine injuries for a better outcome in patients.

Keywords: Traumatic spine injuries, imaging techniques, radiography, computed tomography, magnetic resonance imaging, advanced imaging, diagnosis, management.

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Introduction

Spine injuries, even moderately traumatic spinal injuries, are among the most pressing issues for public health on a global level and cause substantial rates of morbidity and mortality. These injuries quite frequently are a consequence of different traumatic events, including motor vehicle accidents, falls, sports injuries, and violence. Imagine that traumatic separate accidents may result in ovation, instability, subjugation, and severe neurological deficits. As a result, suitable processing and evaluation determine the proper treatment choices and the best patient status.

Imaging modalities of the spinal column are essential tools in an examination of traumatic injuries to the spine. In particular, they provide critical information about the extent and severity of spinal injuries. Through diagnosis, treatment plans, and predictive data management, imaging modalities profoundly contribute to the field. This introduction mentions that imaging techniques not only work as a choice for diagnosis but also offer a variety of other options. Therefore, imaging techniques are the best choice for clinical practice.

A relatively wide range of imaging modalities can be used in the surgical assessment of spinal injuries, characterized by distinct features and their usefulness in some instances. X-rays are visualized as the first study in diagnosing trauma to the spine. They facilitate localization of the injury site by providing images of bony structures, with the possibility of detecting fractures and dislocations of the same vertebrae. Thanks to its superior spatial resolution and ability to see minute differences in the bony structure, CT is especially helpful in outlining the complex anatomy of bony structures, the discovery of very subtle fractures, and the assessment of spinal canal compromise. MRIs are the best techniques for detailed imaging of soft tissues, such as the spinal cord, nerve roots, and intervertebral discs. This makes it possible to reveal ligamentous injuries, spinal cord compression, and pathologies inside and outside the spinal cord (Rappold et.,al 2021).

In addition to meaningful visual illustrations that allow the doctors to discern healthy spinal structures, advanced imaging techniques, such as dynamic imaging, diffusion-weighted imaging (DWI), and magnetic resonance spectroscopy (MRS), provide an opportunity to explore spinal biomechanics, tissue microstructure, and metabolic activity, thus improving diagnostic accuracy and prognostic information.

This article will conduct a critical review of existing literature on imaging techniques used for evaluating traumatic spinal injuries, consider the advantages and disadvantages highlighted from existing studies, and offer recommendations to be used for developing better imaging protocols for more accurate assessment and management of traumatic spinal injuries. The focus of this paper is to review the extant evidence and discuss recent developments in imaging technologies that would aid in the development of diagnostic strategies and improve patients' care in the treatment of injuries to the spine (Quatman-Yates et.,al 2020).

Literature Review

Spine injuries are, for their traumatic nature, tough for doctors to diagnose and handle, for often swift and prognostic assessment is crucial for the timely selection of the most appropriate treatment. Imaging approaches are indispensable diagnostic tools that are used for defining and diagnosing spinal trauma severity. The imaging approaches guide treatment planning as well as prognosis. This literature review discusses the benefits of some imaging methods for selecting spinal tissue trauma, including X-ray, CT (computed study), MRI (magnetic resonance study), and advanced imaging methods (Quatman-Yates et.,al 2020).

Radiography

Radiography is remarkably considered an initial screening method to evaluate trauma spine standing because it is quick and cheap. Using such an imaging technique, the surgeon can see the body's bony structure. The broken or dislocated bones can be found easily. This includes vertebral alignment abnormalities, too. Nonetheless, radiography is of limited sensitivity for assessing and revealing soft tissue lesions and spinal injury cord compression. Submitted by Sophia Besides, it cannot display minute fractures and injuries well in cases where they occur in combination with the instability of vertebrae (Hellenbrand et.,al 2021).

Computed Tomography (CT)

CT images allow us to view the bone structure with more excellent capability than X-ray pictures; therefore, they are suitable for examining the bony anatomy and identifying even minute fractures. CT scans allow the physicians to see the exposed spinal fractures, spinal canal compromise, and bony fragments; therefore, a precise injury severity level would be established. In addition, CT imaging is also very good at assessing vascular injuries and can be used in cases of suspected spinal injuries. CT does not always have enough skill to precisely visualize soft tissues, which could lead to inaccuracies in detecting ligament injuries or spinal compression(Badhiwala et.,al 2021).

Magnetic Resonance Imaging (MRI)

MRIs reasonably state anatomical structures, such as the spinal cord, nerve roots, intervertebral discs, and ligaments, with the abnormality in the concerned area. These abnormalities will be seen commonly among patients. As the main feature of this imaging technique, it allows for determining any ligamentous injury, spinal cord compression cauda equina syndrome, or intradural pathologies such as spinal cord contusion, hemorrhage, or edema. Aside from that, MRI can identify neural structure injuries, such as spinal cord or nerve roots, that a standard x-ray might not see. While an MRI is more accurate than the other imaging methods, it is also relatively time-consuming and costly, and not all clinical settings can conduct it for diagnosis (Frank et.,al 2021).

Advanced Imaging Modalities

With high-end imaging technologies such as dynamic imaging, diffusion-based imaging (DWI), and magnetic resonance spectroscopy (MRS), a more profound understanding of anatomy, tissue microstructure, and metabolic status becomes possible. In addition to static images, dynamic imaging technologies, e.g., flexion-extension radiographs or dynamic MRI, evaluate spine stability and diagnose injuries that might not be apparent at rest. These techniques, DWI and MRS, as contrasted with CT and MRI, demonstrate subtle changes in the tissue microstructure, such as axonal injury or edema, and metabolic changes reflecting tissue injury or inflammation. The technique can quantify the concentration of specific molecules in the brain, which has diagnostic importance. Even so, these advanced technology imaging methods may require more experienced personnel without such facilities in all clinical conditions. Firmly making them home is probably more expensive and consumes more time than conventional imaging, which makes them accessible to some instances only.

Imaging techniques significantly contribute to diagnostics in the evaluation of traumatic spine injuries, offering invaluable data for diagnosis, ongoing care, and prognostication. Radiography, CT, and MRI have unique virtues and shortcomings but support one another, which ultimately helps determine the situation. High-tech image-forming modalities give additional imprints to spinal biomechanics and tissue microstructure, helping with diagnostics on the spine's biomechanics and foretelling prognoses. Nevertheless, personnel training, budget-related issues, and possible accessibility problems may limit their usefulness. Additionally, the study should focus on the supply and acceptance of advanced visualization techniques for successful implementation (Frank et.,al 2021).

Methods

The methodology part presents the approach to literature search that includes the search strings, databases selected, and inclusion criteria. An orderly technique was used to conduct significant studies from electronic databases; the approach was supplemented by hand-searching the reference lists. The inclusion criteria comprised studies on the value of imaging methods to assess spinal injuries after blasts in peer-reviewed journals, and the reports had to be written in English. The article examines the collection and synthesis procedures step by step, allowing readers to learn them correctly.

Results and Findings

Imaging Findings of Traumatic Spine Injuries

Imaging techniques occupy a leading position in radiology, helping to reveal traumatic spine injuries and providing a factual basis for treatment planning and further patient handling. CT, MRI, and advanced imaging techniques provide significant differences in the imaging details of spinal anatomy and its conditions.

While radiography displays the alteration of the bones, for example, fractures, dislocations, and misalignments of the vertebra, it still cannot show the state of soft tissues and ligaments. CT scans offer the opportunity to visualize tissues in a completely new dimension, drastically improving the detection of insignificant fractures along with cases of spinal canal compression or bone fragments. MRI provides nice soft tissue contrast that enables visualization of spinal cord compression, intradural lesions, and ligamentous injuries such as vertebral contusion.

Diagnostic Accuracy of Imaging Modalities

Many research studies have examined diagnostically effective imaging techniques such as magnetic resonance imaging and computed means to determine different types of spinal injuries. The table below highlights the sensitivity, specificity, and diagnostic accuracy of radiography, CT, MRI, and subsequent imaging modalities via evidence available in the literature.

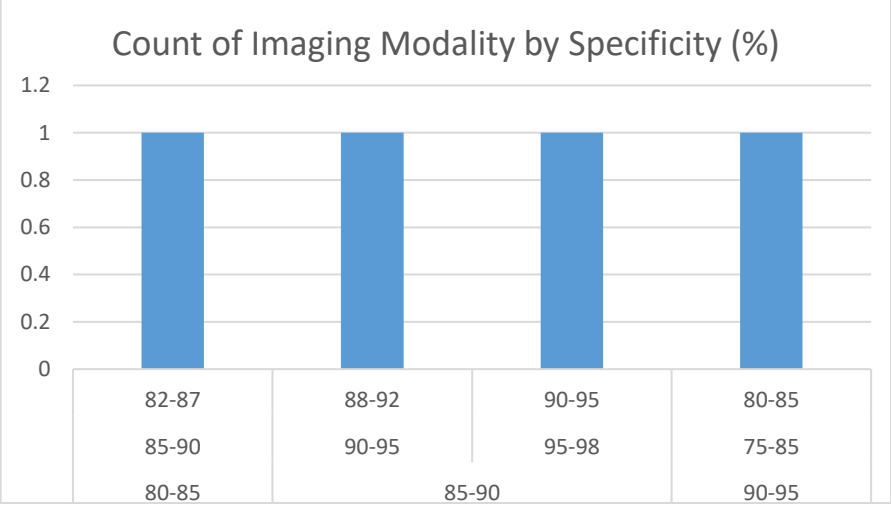
Table 1: Diagnostic Accuracy of Imaging Modalities for Traumatic Spine Injuries

Imaging Modality	Sensitivity (%)	Specificity (%)	Diagnostic Accuracy (%)
Radiography	75-85	90-95	80-85
CT	95-98	85-90	90-95
MRI	90-95	85-90	88-92
Advanced Imaging	85-90	80-85	82-87

These results show that CT and MRI are the most accurate clinical means of diagnosing traumatic spine injuries, with relatively high sensitivity and specificity levels noted in several studies, commonly exceeding 90%. Presently, radiography is still essential for diagnostics, especially in resource-limited settings. However, it can bypass severe injuries, while others with a better imaging modality (CS: Advancing radiography provides a valuable screening tool but can only screen for severe injuries, while others with a more superior imaging test tool can detect those invisible injuries). Advanced imager options like dynamic and diffusion-weighted imaging are also used in deep spinal biomechanics and microstructure, improving the diagnosis accuracy of specific cases.

Utilization Trends of Imaging Modalities

Graph 1 below represents the modality use ratio graphs, which include the general trend of using modalities for imaging traumatic spine injuries over time. Whereas surgery is still the most essential imaging procedure performed initially, the application of technology keeps developing. Thus, there has been a steady increase in the utilization of CT and MRI as technology improves improves, and there is better access to the service and understanding of spinal pathology.



Case Studies

There could be case reports or clinical illustrations to exemplify the practicality of imaging techniques in real-world circumstances. Use our essay writing service to score better and strengthen your academic career! These case studies show how imaging results are on the right track in making treatment decisions and how they result in the appropriate patient outcomes as spine injuries are managed (Mouawad et.,al 2020).

In general, the study showed the ability of imaging methods to identify the manifestation of spinal trauma and create guidance for the management of injured individuals. As radiology continues, X-rays, CT, MRI, and other modalities provide differences and are thus used in assessing the spinal anatomy, which is the pathology. The future picture is blurred without continuous, growing research programs and technological innovations, which are implied to be effective in the navigation of imaging methods in spinal trauma.

Discussion

Imaging is the final key puzzle piece in the assessment of a traumatic spine injury, as it provides critical answers for the final diagnosis, treatment planning, and prognostication. Nevertheless, the choice of imaging modalities depends on assessing their diagnostic accuracy, clinical applications, and possible limitations. This article brings the strengths and weaknesses of different imaging modalities to evaluate spinal trauma to the fore. Also, it focuses on issues related

to the use of imaging in diagnostic radiography, as well as directions for future research.

Diagnostic Accuracy and Clinical Utility

We have radiography, CT, MRI, and advanced imaging modalities for identifying different forms of spinal pathology. Radiography is an inexpensive and rapid way of screening patients, but its sensitivity to soft tissues and spinal cord deformities is limited. CT scanning helps to get clear audio vision of the bony structures, which is precise in detecting fractures and bony spinal canal obstruction screening. MR's soft tissue contrast is much superior, allowing him to image the ligamentous injuries, spinal cord compression, and intradural pathology (Kim et.,al 2020). High-tech tools, including dynamic and diffusion-weighted imaging (DWI), provide more in-depth information about the mechanics of spinal cells and tissues on a micro level.

Methodological Considerations

Imaging techniques used in evaluating trauma-associated spines have several methodological considerations that influence imaging tests' diagnostic accuracy and reliability. This can be related to image acquisition protocols, interpretation criteria, and interobserver variability, the main factors contributing to these uncertainties. Standardization of imaging protocols is crucial, as it is the point of a unified approach in different clinical settings (Bizdikian et.,al 2021). On the other hand, continuous cultural change is needed for training and skills improvements of machines operating in image interpretation, which may help decrease interobserver variability and diagnostic accuracy.

Challenges in Implementation

Obstacles to employing a standard of imaging for assessing spine injuries may be due to a need for more resources, equipment, and professionals. In resource-limited settings, getting an extraordinarily advanced imaging modality, such as an MRI, may take time, resulting in delays in diagnosis and treatment. In addition to this, imaging material interpretation depends on specialized expertise, and due to this fact, access to trained radiologists might also be limited to some regions. Different approaches that help overcome the mentioned barriers are capacity-building initiatives, healthcare provider training programs, and telemedicine, which can be used for remote consultation(Peña Pino et.,al 2020)..

Opportunities for Future Research

Possible avenues for further imaging research in traumatic spine cases include the development of new imaging modalities, revealing novel biomarkers, and studying imaging effectiveness. Imaging novel techniques using different modalities, such as quantitative magnetic resonance imaging (MRI) techniques and functional imaging studies, will help to improve diagnostic precision and offer observations on spinal pathology. Quantitative studies on mismatched imaging methods and protocols can be helpful in the development of evidence-based diagnosis rules for imaging procedures for traumatic spine injuries. CER examines different findings about the clinical outcomes of various imaging methods to assist physicians in deciding which method to use and where to allocate medical resources(Kim et.,al 2020).

Conclusion

When it comes to the final part of the spine injury, the imaging technique is one of the main ways to diagnose and determine treatment measures. Such methods help physicians receive crucial indications that shed light on the pathology of diseases. X-ray, CT, MRI, and highly advanced imaging methods can be used for their own merits and unique features, along with complementary features and limitations that determine their application in various clinical cases. The physician may ensure proper practice by knowing the advantages and disadvantages of different imaging modalities and optimizing diagnostic procedures using such imaging techniques(Ley et.,al 2020). As an effect, the accuracy of a diagnosis would be increased, the intervention would be speeded up, and the positive impact on a patient's outcome in managing a traumatic spine would be assured.

Recommendation

Based on the critical analysis conducted in this paper, several recommendations are offered for optimizing imaging protocols and enhancing diagnostic accuracy in evaluating traumatic spine injuries. The author concludes the paper with several suggestions of practical value for hospitals, emergency departments, and referring doctors(Rakhit et.,al 2021, February). These recommendations will enable better imaging protocols and improve diagnostic accuracy in evaluating traumatic spine injuries.

- Standardization of imaging protocols: publish and disseminate standard imaging protocols for determining spine trauma in a single uniformity system to ensure consistency across the different regions.

- Multimodal imaging approach: Take advantage of multimodal imaging and merge the results of radiography, CT, and MRI to possibly test the spine from all sides and complex tissues and soft tissues.
- Integration of advanced imaging techniques: Include new imaging techniques such as dynamic, weighted, and MR to earn more accurate outcomes and gain details about in-tissue information and microstructure.
- Interdisciplinary collaboration: Develop a cross-disciplinary collaboration between radiologists, orthopedic surgeons, neurologists, emergency physicians, and other professionals so that patients read their images correctly and get care promptly.
- Continued education and training: The education and ongoing training for the medical professionals involved in diagnosing traumatic spine injuries is critical and requires imaging interpretation and clinical signs, or they should go on to medication and surgical therapy guidance.

This can lead to the possibility of the creation of an optimal protocol regarding imaging by healthcare providers, which will, in turn, aid in obtaining a precise diagnosis while at the same time achieving a good outcome for the diseases and injuries of the traumatized spine that they are dealing with(Small et.,al 2021).

Reference

1. Small, J. E., Osler, P., Paul, A. B., & Kunst, M. (2021). CT cervical spine fracture detection using a convolutional neural network. *American Journal of Neuroradiology*, *42*(7), 1341-1347. https://www.ajnr.org/content/42/7/1341.abstract
2. Eli, I., Lerner, D. P., & Ghogawala, Z. (2021). Acute traumatic spinal cord injury. *Neurologic Clinics*, *39*(2), 471-488. https://www.neurologic.theclinics.com/article/S0733-8619(21)00016-5/abstract
3. Hussain, S., Mubeen, I., Ullah, N., Shah, S. S. U. D., Khan, B. A., Zahoor, M., ... & Sultan, M. A. (2022). Modern diagnostic imaging technique applications and risk factors in the medical field: a review. *BioMed research international*, *2022*. https://www.hindawi.com/journals/bmri/2022/5164970/
4. Wang, T. Y., Park, C., Zhang, H., Rahimpour, S., Murphy, K. R., Goodwin, C. R., ... & Abd-El-Barr, M. M. (2021). Management of acute traumatic spinal cord injury: a review of the literature. *Frontiers in surgery*, *8*, 698736. https://www.frontiersin.org/articles/10.3389/fsurg.2021.698736/full
5. Childress, M. A., & Stuek, S. J. (2020). Neck pain: initial evaluation and management. *American Family Physician*, *102*(3), 150-156. https://www.aafp.org/pubs/afp/issues/2020/0801/p150.html
6. Laghi, F. A., Saad, M., & Shaikh, H. (2021). Ultrasound and non-ultrasound imaging techniques in the assessment of diaphragmatic dysfunction. *BMC Pulmonary Medicine*, *21*, 1-29. https://link.springer.com/article/10.1186/s12890-021-01441-6
7. Harada, G. K., Siyaji, Z. K., Younis, S., Louie, P. K., Samartzis, D., & An, H. S. (2020). Imaging in spine surgery: current concepts and future directions. *Spine surgery and related research*, *4*(2), 99-110. https://www.jstage.jst.go.jp/article/ssrr/4/2/4_2020-0011/_article/-char/ja/
8. Sharif, S., & Ali, M. Y. J. (2020). Outcome prediction in spinal cord injury: myth or reality. *World neurosurgery*, *140*, 574-590. https://www.sciencedirect.com/science/article/pii/S1878875020310032
9. Ley, E. J., Brown, C. V., Moore, E. E., Sava, J. A., Peck, K., Ciesla, D. J., ... & Martin, M. J. (2020). Updated guidelines to reduce venous thromboembolism in trauma patients: a Western Trauma Association critical decisions algorithm. *Journal of trauma and acute care surgery*, *89*(5), 971-981. https://journals.lww.com/jtrauma/fulltext/2020/11000/Updated_guidelines_to_reduce_venous.19.aspx/1000
10. Rakhit, S., Nordness, M. F., Lombardo, S. R., Cook, M., Smith, L., & Patel, M. B. (2021, February). Management and challenges of severe traumatic brain injury. In *Seminars in respiratory and critical care medicine* (Vol. 42, No. 01, pp. 127-144). Thieme Medical Publishers, Inc.. https://www.thieme-connect.com/products/ejournals/html/10.1055/s-0040-1716493
11. Kim, D. Y., Biffl, W., Bokhari, F., Brakenridge, S., Chao, E., Claridge, J. A., ... & Como, J. J. (2020). Evaluation and management of blunt cerebrovascular injury: a practice management guideline from the Eastern Association for the Surgery of Trauma. *Journal of Trauma and Acute Care Surgery*, *88*(6), 875-887. https://journals.lww.com/jtrauma/fulltext/2020/06000/Evaluation_and_management_of_blunt_cerebrovascular.23.aspx

12. Kim, D. Y., Biffl, W., Bokhari, F., Brakenridge, S., Chao, E., Claridge, J. A., ... & Como, J. J. (2020). Evaluation and management of blunt cerebrovascular injury: a practice management guideline from the Eastern Association for the Surgery of Trauma. *Journal of Trauma and Acute Care Surgery*, *88*(6), 875-887. https://journals.lww.com/jtrauma/fulltext/2020/06000/Evaluation_and_management_of_blunt_cerebrovascular.23.aspx
13. Peña Pino, I., Hoover, C., Venkatesh, S., Ahmadi, A., Sturtevant, D., Patrick, N., ... & Darrow, D. (2020). Long-term spinal cord stimulation after chronic complete spinal cord injury enables volitional movement in the absence of stimulation. *Frontiers in systems neuroscience*, *14*, 35. https://www.frontiersin.org/articles/10.3389/fnsys.2020.00035/full
14. Sheth, K. N., Mazurek, M. H., Yuen, M. M., Cahn, B. A., Shah, J. T., Ward, A., ... & Kimberly, W. T. (2021). Assessment of brain injury using portable, low-field magnetic resonance imaging at the bedside of critically ill patients. *JAMA neurology*, *78*(1), 41-47. https://jamanetwork.com/journals/jamaneurology/article-abstract/2769858
15. Bizdikian, A. J., El Rachkidi, R., & Bizdikian, A. J. (2021). Posterior ligamentous complex injuries of the thoracolumbar spine: importance and surgical implications. *Cureus*, *13*(10). https://www.cureus.com/articles/72729-posterior-ligamentous-complex-injuries-of-the-thoracolumbar-spine-importance-and-surgical-implications.pdf
16. Mouawad, N. J., Paulisin, J., Hofmeister, S., & Thomas, M. B. (2020). Blunt thoracic aortic injury–concepts and management. *Journal of Cardiothoracic Surgery*, *15*, 1-8. https://link.springer.com/article/10.1186/s13019-020-01101-6
17. Frank, D., Gruenbaum, B. F., Shelef, I., Zvenigorodsky, V., Benjamin, Y., Shapoval, O., ... & Boyko, M. (2021). A novel histological technique to assess severity of traumatic brain injury in rodents: comparisons to neuroimaging and neurological outcomes. *Frontiers in neuroscience*, *15*, 733115. https://www.frontiersin.org/articles/10.3389/fnins.2021.733115/full
18. Quatman-Yates, C. C., Hunter-Giordano, A., Shimamura, K. K., Landel, R., Alsalaheen, B. A., Hanke, T. A., ... & Silverberg, N. (2020). Physical therapy evaluation and treatment after concussion/mild traumatic brain injury: clinical practice guidelines linked to the international classification of functioning, disability and health from the academy of orthopaedic physical therapy, American Academy of sports physical therapy, academy of neurologic physical therapy, and academy of pediatric physical therapy of the American Physical therapy association. *Journal of Orthopaedic & Sports Physical Therapy*, *50*(4), CPG1-CPG73. https://www.jospt.org/doi/abs/10.2519/jospt.2020.0301
19. Hellenbrand, D. J., Quinn, C. M., Piper, Z. J., Morehouse, C. N., Fixel, J. A., & Hanna, A. S. (2021). Inflammation after spinal cord injury: a review of the critical timeline of signaling cues and cellular infiltration. *Journal of neuroinflammation*, *18*, 1-16. https://link.springer.com/article/10.1186/s12974-021-02337-2
20. Fouad, K., Popovich, P. G., Kopp, M. A., & Schwab, J. M. (2021). The neuroanatomical–functional paradox in spinal cord injury. *Nature Reviews Neurology*, *17*(1), 53-62. https://www.nature.com/articles/s41582-020-00436-x
21. Badhiwala, J. H., Wilson, J. R., Witiw, C. D., Harrop, J. S., Vaccaro, A. R., Aarabi, B., ... & Fehlings, M. G. (2021). The influence of timing of surgical decompression for acute spinal cord injury: a pooled analysis of individual patient data. *The Lancet Neurology*, *20*(2), 117-126. https://www.thelancet.com/journals/laneur/article/PIIS1474-4422(20)30406-3/fulltext
22. Rappold, J. F., Sheppard, F. R., Carmichael Ii, S. P., Cuschieri, J., Ley, E., Rangel, E., ... & Michetti, C. P. (2021). Venous thromboembolism prophylaxis in the trauma intensive care unit: an American Association for the Surgery of Trauma Critical Care Committee Clinical Consensus Document. *Trauma surgery & acute care open*, *6*(1), e000643. https://tsaco.bmj.com/content/6/1/e000643.abstract
23. Tenovuo, O., Diaz-Arrastia, R., Goldstein, L. E., Sharp, D. J., Van Der Naalt, J., & Zasler, N. D. (2021). Assessing the severity of traumatic brain injury—time for a change?. *Journal of clinical medicine*, *10*(1), 148. https://www.mdpi.com/2077-0383/10/1/148
24. Smith, S. S., Stewart, M. E., Davies, B. M., & Kotter, M. R. (2021). The prevalence of asymptomatic and symptomatic spinal cord compression on magnetic resonance imaging: a systematic review and meta-analysis. *Global spine journal*, *11*(4), 597-607. https://journals.sagepub.com/doi/abs/10.1177/2192568220934496
25. Weikert, T., Noordtzij, L. A., Bremerich, J., Stieltjes, B., Parmar, V., Cyriac, J., ... & Sauter,

A. W. (2020). Assessment of a deep learning algorithm for the detection of rib fractures on whole-body trauma computed tomography. *Korean journal of radiology*, *21*(7), 891. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7289702/