World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(REVIEW ARTICLE)

MRI as a critical tool in diagnosing complex spine deformities: A review of its diagnostic and management contributions

Md Abrar Alam [1, *], Ashita Jain [2], Arshad Alam Khan [2], Lalramdinmawia Ralte [1] and Sahil Mehra [1]

[1] *Radio-Imaging Technology (MRIT), Department of Paramedical Science, Faculty of Allied Health Science, SGT University, Gurugram-122505.*
[2] *Assistant professor in Radio-Imaging Technology, Department of Paramedical Science, Faculty of Allied Health Science, SGT University, Gurugram -122505*

World Journal of Advanced Research and Reviews, 2025, 25(03), 894-900

Publication history: Received on 02 February 2025; revised on 10 March 2025; accepted on 12 March 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.25.3.0797

Abstract

Background: MRI is a necessary component of diagnosing complicated spine deformities, such as scoliosis, kyphosis and vertebral anomalies. While X rays and CT scan only differentiate between bone and soft tissue, MRI provides high tissue differentiation providing detailed image of both the tissue, thus aiding in diagnosis and treatment planning.

Aim & Objective: This study aims to determine the role of magnetic resonance imaging in the diagnosis and management of complex spine deformities. The goals are to retrospectively evaluate the impact of MRI on diagnosis, follow up and treatment decisions of congenital and degenerative spinal disease.

Methodology: A review of literature was carried out with analysis of peer reviewed studies in the latter two decades. From an initial pool of 36, 18 related articles were selected. These studies addressed the diagnostic properties, accuracy, and clinical management implication of MRI in spine deformities.

Discussion: Considering the accuracy of MRI for assessing myriad spine deformities, the use of MRI in the management of complex spine deformities has certainly changed the way spine deformities are managed, allowing for accurate, non-invasive images that can contribute to accurate diagnosis and improve outcomes of surgical planning and monitoring the degenerative conditions within the spine.

Conclusion: MRI has become a great diagnostic and management modality for complex spine deformities. Clinically, its capability to produce detailed, non-invasive, nonionizing radiation images which help facility decision making, surgical planning, and disease monitoring ultimately to enhance patient outcomes and treatment strategies.

Keywords: MRI; Spine deformities; Intraspinal anomalies; Degenerative conditions; Diagnostic accuracy; Treatment planning

1. Introduction

Magnetic Resonance Imaging (MRI) has emerged as an essential diagnostic modality in the evaluation and management of complex spine deformities, where it is unparalleled for its ability to capture exquisite images of the spine's soft tissues, spinal cord, and intraspinal abnormalities and thus be the reference standard in the assessment of spinal trauma. Anatomically complex and often progressive, spine deformities, such as scoliosis, kyphosis, and vertebral anomalies require accurate diagnosis to enable effective treatment planning. Because of these cases, MRI has become a gold

* Corresponding author: Abrar Alam

standard imaging modality in comparison to traditional imaging techniques including; X-rays and CT scans, it is non-invasive and provides superior soft tissue contrast.[1]

Because of their complex structural changes and associated intraspinal anomalies, there is a lack of sensitivity inherent in the conventional imaging methods for evaluating spinal deformity. MRI allows for clear images of spine as well as surround abnormalities. This is important in congenital deformities where MRI can identify intraspinal problems such as tethered cord, syringomyelia, diastematomyelia and help decide whether to act surgically or not. MRI is additionally important in identification of cervical abnormalities in patients with severe spinal deformities to guide clinical management--it describes the structural sequelae in the cervical region.[2] Preoperative evaluations utilizing MRI is now widely performed, particularly in adolescent idiopathic scoliosis. Somehow it can detect obscure intraspinal pathologies like Chiari malformation that other imaging methods miss. These abnormalities need to be identified in order for surgical planning to proceed as these abnormalities can significantly affect the approach and correction involved, reducing the risk of neurologic complications.[3]

As in Scheuermann's kyphosis, MRI has been of crucial importance in diagnosing and excluding other causes of deformity, and MRI screening in operative Scheuermann kyphosis is highlighted as essential to understanding the structural deformities and intraspinal changes to provide insights as to whether surgical treatment is indicated. MRI has not only resulted in improving the ability of clinicians to diagnose with more accuracy, but has also created a better means of matching treatment outcomes with surgical resolution.[4] Damage to the degenerative spinal conditions and tracking the progression is the responsibility of MRI. Vertebral endplate degeneration, a cause of low back pain and degenerative scoliosis, is evaluated. Monitoring spinal degeneration and predicting outcomes require MRI which reveals changes X-rays often miss.[5] In a similar vein, it was demonstrated the significance of MRI in evaluating spinal positioning in athletes, showcasing its utility beyond simple static images and into more dynamic analyses of spinal mechanics.[6] The diagnostic potential of MRI further develops with new developments such as deep learning applications to measure vertebral deformity. Artificial intelligence can enhance MRI capabilities of measuring deformities by better accuracy in deformities diagnosis and prognosis was discussed.[7]

MR has become a fundamental diagnostic and management tool for the complex spine deformities. It plays a critical role in understanding the details of spine deformities because with its ability to provide high resolution, detailed images of both bone and soft tissue structures. This paper will follow to explore MRI's specific diagnostic capabilities and the contribution of MRI to clinical decision-making in surgical and non-surgical management.

1.1. The Purpose of this review

This study is intended to be a broad review of Magnetic Resonance Imaging (MRI) contribution to the diagnosis and management of complex spine deformities. Diagnosis and treatment of spine deformities (such as scoliosis, kyphosis and vertebral anomalies) also pose special challenges. This study will evaluate existing literature and clinical studies to determine how MRI improves diagnostic accuracy, and how it can affect treatment decisions, and monitoring of disease progression, in these cases. This review synthesizes findings from recent research to emphasize the critical role of MRI in congenital and degenerative spinal deformity with consideration of its current and future contribution to clinical practice.

2. Methodology

2.1. Study Design and Search strategies

The methodology adopted for this study is based on systematic literature review methodology, which consists of the identification, selection and analysis of relevant peer reviewed journal articles. The search began with a systematic search of electronic databases, such as PubMed, ScienceDirect and Google Scholar of published articles in the recent two decades. Studies were identified using keywords such as 'MRI', spine deformities', 'scoliosis', 'kyphosis', 'vertebral anomalies', 'diagnosis'. We initially identified 200 records, of which 100 articles were screened, and 18 articles were selected based on their relevance to the topic of the study and especially on those concerning the role of MRI in diagnosing and managing complex spine deformities. Detailed analysis of how the selected articles provide critical information about the accuracy, clinical utility and treatment implications of MRI.

Aim and Objective

The primary aim of this study is to explore and critically evaluate the contributions of MRI as a diagnostic and management tool for complex spine deformities. The objectives of this review are as follows:

- To analyse the role of MRI in detecting intraspinal anomalies associated with congenital spine deformities.
- To examine the utility of MRI in monitoring the progression of degenerative spine deformities.
- To provide recommendations for clinical practice based on the synthesized evidence.

2.1.1. Inclusion Criteria

- Studies on patients with complex spine deformities (e.g., scoliosis, kyphosis, neurofibromatosis-related deformities).
- Research focusing on MRI for diagnosis, surgical planning, or management.
- Reports on MRI's diagnostic accuracy or its impact on treatment decisions.
- Peer-reviewed studies, systematic reviews, or meta-analyses in English.

2.1.2. Exclusion Criteria

- Studies not related to spine deformities (e.g., isolated degenerative changes).
- Research focused on non-MRI imaging without comparison to MRI.
- Outdated MRI techniques or irrelevant experimental methods.

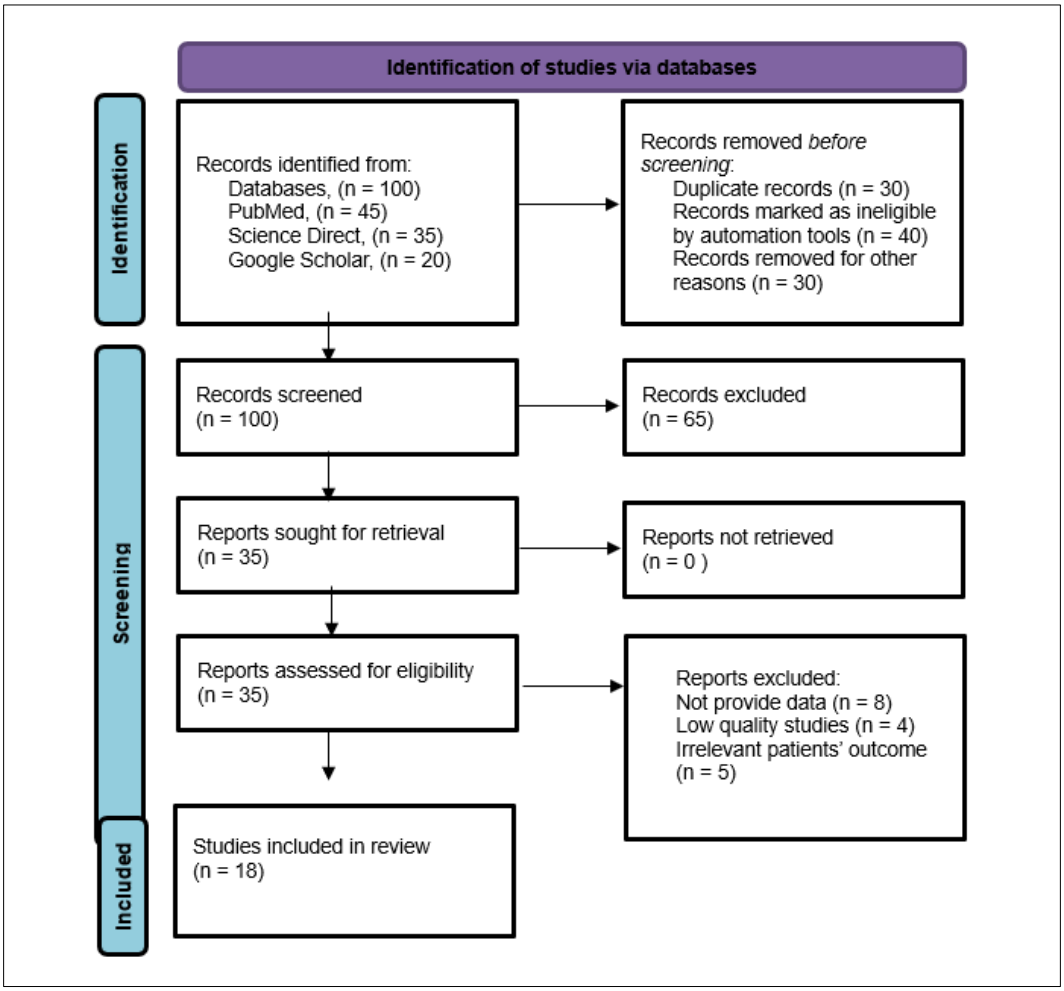

Figure 1 The 100 original research papers appear in Fig. showing the PRISMA distribution. From those, we chose 18 papers, which had interesting information. All these are illustrated in the figure

3. Discussion

The use of Magnetic Resonance Imaging (MRI) has provided tremendous insight into osseous and soft tissue structures of the complex spine deformities and has revolutionized the diagnosis and management of these spine deformities without the use of ionizing radiation. It has wide spanning applications that involve major contributions to patient care and clinical outcomes in a wide range of spinal pathologies.

3.1. Role of MRI in Degenerative Spinal Deformities

MRI is essential in evaluating degenerative spinal condition by identifying various disc degenerative features, endplate changes and ligamentous structures to enable diagnosis and treatment planning. Accordingly, Siepe et al. (2012) [8] indicated that the total lumbar disc replacement outcomes depend on the degree of lumbar intervertebral disc degeneration on MRI and gave special emphasis on the importance of detailed preoperative imaging to predict surgical success and tailor interventions. MRI in low back pain due to vertebral endplate degeneration was emphasized by Din et al. (2022) [9] as guiding appropriate therapeutic strategies, by identifying Modic changes and endplate defects. Also, Van Der Graaf et al. (2023) [10] performed a narrative review that included specific MRI patterns associated with low back pain, improving clinicians' ability to correlate imaging findings with patients' symptoms for optimal patient care. More aggressive studies of asymptomatic disc abnormalities on MRI found that some imaging features could predict the future development of low back pain related medical consultations and work incapacity, demonstrating that MRI has a place in risk stratification and preventive strategies.[11]

3.2. MRI in Scoliosis

MRI plays an essential role in the evaluation of scoliosis, including in the detection of intraspinal anomalies that may not be apparent on radiographs and is used to affect diagnosis and preoperative planning. Zhang et al. (2016) [12] who performed an MRI-based analysis of 504 patients presumed to have idiopathic scoliosis, showed a remarkably high prevalence (17%) of intraspinal anomalies in early (infantile and juvenile) patients, endorsing routine MRI screening to prevent potentially neurological complications if and when the derangement is corrected. MR techniques have advanced beyond conventional imaging capabilities and Schmitz et al. (2001) [13] present a new MRI technique for sagittal plane imaging of scoliosis to visualize spinal curvature and assist in precise planning of surgery. Redla et al. (2001) [14] described how more advanced technology has facilitated better imaging of spinal deformities and associated abnormalities allowing MRI to play a valuable role in scoliosis management.

3.3. MRI in Neurofibromatosis Type 1

Patients with Neurofibromatosis Type 1 often have complex spinal deformity and require comprehensive whole spine MRI. MRI is emphasized by Ramachandran et al. (2004) [15] for detecting dystrophic changes, intraspinal tumors, and associated pathologies aiding in determining appropriate management strategies and avoiding intraoperative complications by delineating spinal extent of involvement.

3.4. MRI in Traumatic Spine Injuries

In acute spinal trauma, MRI is important for identification of soft tissue and ligamentous injury beyond that obtainable on CT scans and thus influences treatment decisions. Khurana et al. (2019) [16] evaluated whether MRI provides sufficient information for treatment decision making in thoracic and lumbar spine fractures noted on whole spine CT and showed that MRI plays an important role in elucidating the extent of soft tissue injury and fracture stability. In their study, Mehta et al. (2021) [17] proceeded similarly to evaluate the diagnostic accuracy of MRI in identifying injuries of the posterior ligamentous complex of the thoracolumbar spine, all of which are important for appropriate surgery.

3.5. MRI in Inflammatory Spinal Conditions

MRI is also very good at showing early inflammatory changes in the spine and sacroiliac joints, the key for early diagnosis and treatment of inflammatory conditions like spondyloarthritis and ankylosing spondylitis. MRI was highlighted by Del Grande et al. (2011) [18] as superior at identifying early spondyloarthritis changes such that timely intervention with disease modifying therapy can prevent disease progression. MRI features of transverse myelitis and arachnoiditis in patients with long-standing ankylosing spondylitis with cauda equina syndrome were presented by Lan et al. (2007) [19] showing the central role of MRI findings in patient management and prognosis.

3.6. MRI in Spinal Infections

Accurate diagnosis of spinal infection prevents serious complications, and MRI is the imaging modality of choice for diagnosis. Shashikumar et al. (2015) [20] used MRI to fill a massive void in our understanding of the degree of spinal tuberculosis, especially image of paravertebral abscess and involvement of adjacent structures which is vital for medical and surgical treatments.

3.7. MRI in Osteoporotic Fractures Leading to Kyphosis

MRI helps preoperatively assess deformity flexibility and spinal cord integrity in patients with kyphotic deformities caused by osteoporotic fractures. Wang et al. (2023) [21] used the preoperative MRI to evaluate whether patients with kyphosis after old osteoporotic thoracolumbar fractures can be assessed by sagittal kyphotic flexibility and whether this MRI can predict spinal flexibility and influence the choice of surgical technique. Additionally, Kaiser et al. (2017) [22] examined how the MRI can predict flexibility in Scheuermann's kyphosis patients and determined that the MRI can be used to predict deformity rigidity and assist in preoperative planning by studying the surgery approach.

3.8. MRI in Sports Medicine

Repeated activities subject athletes to stress injuries and early diagnosis is important to prevent more serious ones. The systematic review of MRI's diagnostic accuracy in identifying posterior bone stress injuries in athletes with low back pain carried by Esh et al. (2020) [23] demonstrated that MRI does well to identify early stress reactions and capture them early so timely intervention and appropriate management can be undertaken to reduce downtime and suppress it from advancing.

3.9. MRI in Prognostication of Spinal Deformities

MRI parameters can be prognostic and indicate clinical outcomes and guide individualized treatment planning in spinal deformities. Zhou et al. (2019) [24] have determined if the parameter of lumbar lordosis minus thoracic kyphosis on MRI can predict clinical outcomes in patients with adult degenerative scoliosis, and MRI measurements predict outcomes as well as help to inform surgical planning.

3.10. Advancements in MRI Techniques

Improvements to MRI technology have allowed the modality to become more patient, friendly and more efficient, improving diagnostic capabilities. Innovative MRI technique for scoliosis sagittal plane imaging:' an improvement of assessment of spinal curvature and alignment without ionizing radiation (Schmitz et al, 2001)[13]. Modern MRI protocols allowing scan times to be reduced while maintaining image quality and improved visualization of spinal deformities and associated abnormalities have been hypothesized to improve patient care (Redla et al., 2001)[14].

3.11. MRI in Lumbar Disc Degenerative Disease

Despite all of the available imaging and surgery for the management of disc degeneration, MRI remains the gold standard for evaluating lumbar disc degenerative disease and influences diagnosis and management as it provides detailed images of disc herniation, spinal stenosis, and other degenerative changes. The use of MRI to assess lumbar disc degeneration has resulted in its effectiveness as measured in Suthar (2015) [25] allowing clinicians to implement treatment plans that are as specific as the location and extent of pathology is to ensure successful patient outcomes.

3.12. MRI in Predicting Low Back Pain Outcomes

Early intervention strategies can be guided by the results of MRI findings predicting the likelihood that patients will seek medical consultation for low back pain and the likelihood of work incapacity. In an investigation of asymptomatic disc abnormalities on MRI, Boos et al (2000)[11] determined predictors of low back pain–related medical consultation and work incapacity, highlighting the use of MRI in assessing, and taking preventative steps for risk.

4. Conclusion

Magnetic Resonance Imaging (MRI) is undeniably a critical tool in the diagnosis and management of complex spine deformities. Its advanced imaging capabilities provide detailed visualization of spinal anatomy and pathology, enabling accurate diagnoses and informed treatment decisions. MRI's ability to detect intraspinal anomalies, assess spinal alignment, and evaluate soft tissue structures without exposure to ionizing radiation makes it indispensable in both clinical and surgical settings. In surgical planning, MRI offers precise images that aid surgeons in strategizing effective corrective procedures, ultimately enhancing patient outcomes. It also plays a vital role in distinguishing between symptomatic and asymptomatic degenerative changes, ensuring that treatment approaches are appropriately tailored to each patient's clinical presentation. While MRI's benefits are substantial, its use should be guided by clinical indications to optimize resource utilization without compromising patient care. Selective application ensures that patients receive the most appropriate imaging based on their specific needs.

MRI significantly enhances the diagnosis and management of complex spine deformities. Its contributions lead to better-informed clinical decisions and improved patient outcomes, solidifying its role as an invaluable asset in spine healthcare.

Compliance with ethical standards

Disclosure of conflict of interest

No conflicts of interest.

References

[1] S.-W. Suh, J. F. Sarwark, A. Vora, and B. K. Huang, "Evaluating Congenital Spine Deformities for Intraspinal Anomalies With Magnetic Resonance Imaging:," J. Pediatr. Orthop., vol. 21, no. 4, pp. 525–531, Jul. 2001, doi: 10.1097/01241398-200107000-00021.

[2] Y. Zhang et al., "Cervical Abnormalities in Severe Spinal Deformity: A 10-year MRI Review," Orthop. Surg., vol. 12, no. 3, pp. 761–769, Jun. 2020, doi: 10.1111/os.12673.

[3] C. Ozturk, S. Karadereler, I. Ornek, M. Enercan, K. Ganiyusufoglu, and A. Hamzaoglu, "The role of routine magnetic resonance imaging in the preoperative evaluation of adolescent idiopathic scoliosis," Int. Orthop., vol. 34, no. 4, pp. 543–546, Apr. 2010, doi: 10.1007/s00264-009-0817-y.

[4] B. S. Lonner et al., "MRI Screening in Operative Scheuermann Kyphosis: Is it Necessary?," Spine Deform., vol. 5, no. 2, pp. 124–133, Mar. 2017, doi: 10.1016/j.jspd.2016.10.008.

[5] J. Takatalo et al., "Prevalence of Degenerative Imaging Findings in Lumbar Magnetic Resonance Imaging Among Young Adults:," Spine, vol. 34, no. 16, pp. 1716–1721, Jul. 2009, doi: 10.1097/BRS.0b013e3181ac5fec.

[6] L. Fawcett, S. James, R. Botchu, J. Martin, N. R. Heneghan, and A. Rushton, "The influence of spinal position on imaging findings: an observational study of thoracolumbar spine upright MRI in elite gymnasts," Eur. Spine J., vol. 31, no. 2, pp. 225–232, Feb. 2022, doi: 10.1007/s00586-021-06997-9.

[7] A. Suri et al., "Vertebral Deformity Measurements at MRI, CT, and Radiography Using Deep Learning," Radiol. Artif. Intell., vol. 4, no. 1, p. e210015, Jan. 2022, doi: 10.1148/ryai.2021210015.

[8] C. J. Siepe et al., "Influence of lumbar intervertebral disc degeneration on the outcome of total lumbar disc replacement: a prospective clinical, histological, X-ray and MRI investigation," Eur. Spine J., vol. 21, no. 11, pp. 2287–2299, Nov. 2012, doi: 10.1007/s00586-012-2342-8.

[9] R. U. Din, X. Cheng, and H. Yang, "Diagnostic Role of Magnetic Resonance Imaging in Low Back Pain Caused by Vertebral Endplate Degeneration," J. Magn. Reson. Imaging, vol. 55, no. 3, pp. 755–771, Mar. 2022, doi: 10.1002/jmri.27858.

[10] J. W. Van Der Graaf, R. J. Kroeze, C. F. M. Buckens, N. Lessmann, and M. L. Van Hooff, "MRI image features with an evident relation to low back pain: a narrative review," Eur. Spine J., vol. 32, no. 5, pp. 1830–1841, May 2023, doi: 10.1007/s00586-023-07602-x.

[11] N. Boos et al., "Natural History of Individuals With Asymptomatic Disc Abnormalities in Magnetic Resonance Imaging: Predictors of Low Back Pain–Related Medical Consultation and Work Incapacity," Spine, vol. 25, no. 12, pp. 1484–1492, Jun. 2000, doi: 10.1097/00007632-200006150-00006.

[12] W. Zhang, S. Sha, L. Xu, Z. Liu, Y. Qiu, and Z. Zhu, "The prevalence of intraspinal anomalies in infantile and juvenile patients with 'presumed idiopathic' scoliosis: a MRI-based analysis of 504 patients," BMC Musculoskelet. Disord., vol. 17, no. 1, p. 189, Dec. 2016, doi: 10.1186/s12891-016-1026-7.

[13] A. Schmitz et al., "A new MRI technique for imaging scoliosis in the sagittal plane," Eur. Spine J., vol. 10, no. 2, pp. 114–117, Apr. 2001, doi: 10.1007/s005860100250.

[14] S. Redla, T. Sikdar, and A. Saifuddin, "Magnetic Resonance Imaging of Scoliosis," Clin. Radiol., vol. 56, no. 5, pp. 360–371, May 2001, doi: 10.1053/crad.2001.0676.

[15] M. Ramachandran, A. I. Tsirikos, J. Lee, and A. Saifuddin, "Whole-Spine Magnetic Resonance Imaging in Patients with Neurofibromatosis Type 1 and Spinal Deformity," J. Spinal Disord. Tech., vol. 17, no. 6, pp. 483–491, Dec. 2004, doi: 10.1097/01.bsd.0000133466.97241.50.

[16] B. Khurana et al., "Is focused magnetic resonance imaging adequate for treatment decision making in acute traumatic thoracic and lumbar spine fractures seen on whole spine computed tomography?," Spine J., vol. 19, no. 3, pp. 403–410, Mar. 2019, doi: 10.1016/j.spinee.2018.08.010.

[17] G. Mehta, U. C. Shetty, D. Meena, A. K. Tiwari, K. G. Nama, and D. Aseri, "Evaluation of Diagnostic Accuracy of Magnetic Resonance Imaging in Posterior Ligamentum Complex Injury of Thoracolumbar Spine," Asian Spine J., vol. 15, no. 3, pp. 333–339, Jun. 2021, doi: 10.31616/asj.2020.0027.

[18] F. Del Grande, J. A. Carrino, and M. Zanetti, "Magnetic Resonance Imaging of Spondyloarthritis: Spine and SI Joints," Top. Magn. Reson. Imaging, vol. 22, no. 2, pp. 83–88, Apr. 2011, doi: 10.1097/RMR.0b013e318259f5c2.

[19] H. H.-C. Lan, D.-Y. Chen, C. C.-C. Chen, J.-L. Lan, and C.-W. Hsieh, "Combination of transverse myelitis and arachnoiditis in cauda equina syndrome of long-standing ankylosing spondylitis: MRI features and its role in clinical management," Clin. Rheumatol., vol. 26, no. 11, pp. 1963–1967, Sep. 2007, doi: 10.1007/s10067-007-0593-2.

[20] S. M.R., B. S.B., V. Joshi, N. C.P., and R. N.L., "Role of MRI in the evaluation of spinal tuberculosis," Int. J. Res. Med. Sci., pp. 1839–1843, 2015, doi: 10.18203/2320-6012.ijrms20150282.

[21] K. Wang et al., "Can preoperative magnetic resonance imaging be used for sagittal kyphotic flexibility assessment in patients with kyphosis secondary to symptomatic old osteoporotic thoracolumbar fracture?," J. Orthop. Surg., vol. 18, no. 1, p. 133, Feb. 2023, doi: 10.1186/s13018-023-03624-9.

[22] R. Kaiser, E. Behrbalk, M. Walsh, P. Waldauf, A. B. Perez Romera, and H. Mehdian, "Can MRI Predict Flexibility in Scheuermann Kyphosis Patients?," Clin. Spine Surg. Spine Publ., vol. 30, no. 7, pp. E938–E941, Aug. 2017, doi: 10.1097/BSD.0000000000000346.

[23] R. Esh et al., "Diagnostic accuracy of MRI for identifying posterior element bone stress injury in athletes with low back pain: a systematic review and narrative synthesis," BMJ Open Sport Exerc. Med., vol. 6, no. 1, p. e000764, Oct. 2020, doi: 10.1136/bmjsem-2020-000764.

[24] S. Zhou et al., "Does lumbar lordosis minus thoracic kyphosis predict the clinical outcome of patients with adult degenerative scoliosis?," J. Orthop. Surg., vol. 14, no. 1, p. 290, Dec. 2019, doi: 10.1186/s13018-019-1339-y.

[25] P. Suthar, "MRI Evaluation of Lumbar Disc Degenerative Disease," J. Clin. Diagn. Res., 2015, doi: 10.7860/JCDR/2015/11927.5761.