Spine • 2025 • Article number 10.1097/BRS.0000000000005236

Document type
Article

Source type
Journal

ISSN
03622436

DOI
10.1097/BRS.0000000000005236

View more

Assessing the Utility and Challenges of Machine Learning in Spinal Deformity Management: A Systematic Review

Khan, Jibran A.[a] ; Houdane, Abdelrafour[a] ; Hajja, Amro[a] ; Nassar, Joseph E.[b] ; Alsoof, Daniel[b] ; Diebo, Bassel G.[b] ; Sardar, Zeeshan M.[c] ; Abd-El-Barr, Muhammad M.[d] ; Bourghli, Anouar[e] ; Konbaz, Faisal[e]

Save all to author list

[a] Alfaisal University College of Medicine, Riyadh, Saudi Arabia

[b] Department of Orthopaedic Surgery, Warren Alpert Medical School of Brown University, Providence, RI, United States

[c] Department of Orthopaedic Surgery, Columbia University Medical Center, The Spine Hospital at New York Presbyterian, New York, United States

[d] Department of Neurosurgery, Duke University Medical Center, Durham, NC, United States

View additional affiliations

Full text options Export

Abstract
Author keywords
SciVal Topics
Metrics

Abstract

Study design. Systematic review Objective. To review the application of machine learning (ML) in scoliosis management, while addressing the limitations and challenges in implementing ML in scoliosis practice. Summary of Background Data. ML has revolutionized medical research, particularly in scoliosis management, enabling automated assessment of diagnosis, disease progression, and treatment response. Methods. A systematic review of the literature was conducted following the PRISMA guidelines and was registered in the PROSPERO database. The literature search included the PubMed, Embase, and Google Scholar databases. Studies since 2019 were included if they used ML models in scoliosis management. Studies that did not meet the inclusion criteria were excluded. Data extraction focused on the scoliosis type, sample size, model utility, ML model architecture, model development, training data, cross-validation, single- or multi-center study design, and study/model limitations. Results. The study included 63 articles that underwent full-text review. The most commonly studied disorders were adolescent idiopathic scoliosis (n=48) and adult spinal deformity (n=15), with five studies including other disorders and one not specifying. The uses of ML were diagnosis/classification (n=38), operative outcomes (n=11), prognosis (n=7), and risk assessment (n=7). The most used models included convolutional neural networks (n=38), random forest (n=11), and support vector machines (n=9). Only 16 studies reported external validation, while none implemented their model in practice. Common limitations reported were small sample size, artifacts obscuring images, potential selection bias, limited variety in disease severity, exclusion of parameters, lack of patient diversity, varying accuracy with curve site and severity, retrospective study, and lack of external validation. Conclusion. The current state of machine learning in scoliosis

management is promising, showing potential for improving diagnosis and optimizing treatments. However, significant challenges remain. To fully understand the benefits of ML, larger, multi-center studies with more validation and effective implementation strategies are needed.

Author keywords

adolescent idiopathic scoliosis; adult spinal deformity; algorithm training; convolutional neural networks; diagnosis; disease progression; early-onset scoliosis; machine learning; model validation; operative outcomes; predictive modelling; random forests; support vector machines; treatment planning

SciVal Topics

Metrics

References (77)

View in search results format >

All

Export Print E-mail Save to PDF Create bibliography

1 Durand, W.M., Lafage, R., Hamilton, D.K., Passias, P.G., Kim, H.J., Protopsaltis, T., Lafage, V., (...), Daniels, A.H.

Artificial intelligence clustering of adult spinal deformity sagittal plane morphology predicts surgical characteristics, alignment, and outcomes

(2021) *European Spine Journal*, 30 (8), pp. 2157-2166. Cited 28 times.
https://link.springer.com/journal/586
doi: 10.1007/s00586-021-06799-z

View at Publisher

2 Fields, M.W., Zaifman, J., Malka, M.S., Lee, N.J., Rymond, C.C., Simhon, M.E., Quan, T., (...), Vitale, M.G.

Utilizing a comprehensive machine learning approach to identify patients at high risk for extended length of stay following spinal deformity surgery in pediatric patients with early onset scoliosis (Open Access)

(2024) *Spine Deformity*, 12 (5), pp. 1477-1483. Cited 2 times.
https://www.springer.com/journal/43390
doi: 10.1007/s43390-024-00889-w

View at Publisher

3 Yang, J., Zhang, K., Fan, H., Huang, Z., Xiang, Y., Yang, J., He, L., (...), Lin, H.

Development and validation of deep learning algorithms for scoliosis screening using back images

(2019) *Communications Biology*, 2 (1), art. no. 390. Cited 110 times.
nature.com/commsbio/
doi: 10.1038/s42003-019-0635-8

View at Publisher

4 Lv, Z., Lv, W., Wang, L., Ou, J.

Development and validation of machine learning-based models for prediction of adolescent idiopathic scoliosis: A retrospective study

(2023) *Medicine (United States)*, 102 (14), p. E33441. Cited 8 times.
https://journals.lww.com/md-journal/pages/default.aspx
doi: 10.1097/MD.0000000000033441

View at Publisher

5 Wolff, R.F., Moons, K.G.M., Riley, R.D., Whiting, P.F., Westwood, M., Collins, G.S., Reitsma, J.B., (...), Mallett, S.

PROBAST: A tool to assess the risk of bias and applicability of prediction model studies (Open Access)

(2019) *Annals of Internal Medicine*, 170 (1), pp. 51-58. Cited 1513 times.
http://annals.org/aim/fullarticle/2719961/probast-tool-assess-risk-bias-applicability-prediction-model-studies
doi: 10.7326/M18-1376

View at Publisher

6 Whiting, P.F., Rutjes, A.W.S., Westwood, M.E., Mallett, S., Deeks, J.J., Reitsma, J.B., Leeflang, M.M.G., (...), Bossuyt, P.M.M.

Quadas-2: A revised tool for the quality assessment of diagnostic accuracy studies

(2011) *Annals of Internal Medicine*, 155 (8), pp. 529-536. Cited 10371 times.
http://www.annals.org/content/155/8/529.full.pdf+html
doi: 10.7326/0003-4819-155-8-201110180-00009

View at Publisher

7 Zhang, B., Chen, K., Yuan, H., Liao, Z., Zhou, T., Guo, W., Zhao, S., (...), Su, P.

Automatic Lenke classification of adolescent idiopathic scoliosis with deep learning (Open Access)

(2024) *JOR Spine*, 7 (2), art. no. e1327. Cited 6 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2572-1143
doi: 10.1002/jsp2.1327

View at Publisher

8 Lullo, B.R., Cahill, P.J., Flynn, J.M., Anari, J.B.

Predicting early return to the operating room in early-onset scoliosis patients using machine learning techniques (Open Access)

(2024) *Spine Deformity*, 12 (4), pp. 1165-1172.
https://www.springer.com/journal/43390
doi: 10.1007/s43390-024-00848-5

View at Publisher

9 Ni, L., Zhang, Z., Zou, L., Wang, J., Guo, L., Qian, W., Xu, L., (...), Zeng, Y.

Clinical Application of Automatic Assessment of Scoliosis Cobb Angle Based on Deep Learning (Open Access)

(2024) *Current Medical Imaging*, 20, art. no. e15734056278130. Cited 4 times.
https://www.eurekaselect.com/article/138811
doi: 10.2174/0115734056278130231218073650

View at Publisher

10 van der Graaf, J.W., van Hooff, M.L., van Ginneken, B., Huisman, M., Rutten,

M., Lamers, D., Lessmann, N., (...), de Kleuver, M.

Development and validation of AI-based automatic measurement of coronal Cobb angles in degenerative scoliosis using sagittal lumbar MRI (Open Access)

(2024) *European Radiology*, 34 (9), pp. 5748-5757. Cited 5 times.
https://www.springer.com/journal/330
doi: 10.1007/s00330-024-10616-8

View at Publisher

11 Wang, M.X., Kim, J.K., Choi, J.-W., Park, D., Chang, M.C.

Deep learning algorithm for automatically measuring Cobb angle in patients with idiopathic scoliosis (Open Access)

(2024) *European Spine Journal*, 33 (11), pp. 4155-4163. Cited 3 times.
https://www.springer.com/journal/586
doi: 10.1007/s00586-023-08024-5

View at Publisher

12 Alfraihat, A., Samdani, A.F., Balasubramanian, S.

Predicting radiographic outcomes of vertebral body tethering in adolescent idiopathic scoliosis patients using machine learning

(2024) *PLoS ONE*, 19 (1 January), art. no. e0296739. Cited 5 times.
https://journals.plos.org//plosone/article?id=10.1371/journal.pone.0296739
doi: 10.1371/journal.pone.0296739

View at Publisher

13 Wong, J., Reformat, M., Lou, E.

Applying Machine Learning and Point-Set Registration to Automatically Measure the Severity of Spinal Curvature on Radiographs (Open Access)

(2024) *IEEE Journal of Translational Engineering in Health and Medicine*, 12, pp. 151-161. Cited 2 times.
http://ieeexplore.ieee.org/servlet/opac?punumber=6221039
doi: 10.1109/JTEHM.2023.3332618

View at Publisher

14 Berlin, C., Adomeit, S., Grover, P., Dreischarf, M., Halm, H., Dürr, O., Obid, P.

Novel AI-Based Algorithm for the Automated Computation of Coronal Parameters in Adolescent Idiopathic Scoliosis Patients: A Validation Study on 100 Preoperative Full Spine X-Rays (Open Access)

(2024) *Global Spine Journal*, 14 (6), pp. 1728-1737. Cited 18 times.
https://journals.sagepub.com/home/GSJ
doi: 10.1177/21925682231154543

View at Publisher

15 Huang, X., Luo, M., Liu, L., Wu, D., You, X., Deng, Z., Xiu, P., (...), Huang, S.

The Comparison of Convolutional Neural Networks and the Manual Measurement of Cobb Angle in Adolescent Idiopathic Scoliosis (Open Access)

(2024) *Global Spine Journal*, 14 (1), pp. 159-168. Cited 9 times.
https://journals.sagepub.com/home/GSJ

doi: 10.1177/21925682221098672

View at Publisher

16 Maaliw, R.R.

SCOLIONET: An Automated Scoliosis Cobb Angle Quantification Using Enhanced X-ray Images and Deep Learning Models

(2023) *Journal of Imaging*, 9 (12), art. no. 265. Cited 5 times.
www.mdpi.com/journal/jimaging/
doi: 10.3390/jimaging9120265

View at Publisher

17 Minotti, M., Negrini, S., Cina, A., Galbusera, F., Zaina, F., Bassani, T.

Deep learning prediction of curve severity from rasterstereographic back images in adolescent idiopathic scoliosis

(2024) *European Spine Journal*, 33 (11), pp. 4164-4170. Cited 3 times.
https://www.springer.com/journal/586
doi: 10.1007/s00586-023-08052-1

View at Publisher

18 Chu, K., Kuang, X., Cheung, P.W.H., Li, S., Zhang, T., Cheung, J.P.Y.

Predicting Progression in Adolescent Idiopathic Scoliosis at the First Visit by Integrating 2D Imaging and 1D Clinical Information (Open Access)

(2025) *Global Spine Journal*, 15 (2), pp. 770-781. Cited 2 times.
https://journals.sagepub.com/home/GSJ
doi: 10.1177/21925682231211273

View at Publisher

19 Wong, J.C., Reformat, M.Z., Parent, E.C., Stampe, K.P., Southon Hryniuk, S.C., Lou, E.H.

Validation of an artificial intelligence-based method to automate Cobb angle measurement on spinal radiographs of children with adolescent idiopathic scoliosis (Open Access)

(2023) *European Journal of Physical and Rehabilitation Medicine*, 59 (4), pp. 535-542. Cited 11 times.
https://www.minervamedica.it/en/getfreepdf/U0IvcjlXcEdkbWF0YlRGQnZLZEdsYTZkWTdSS2FENDR1WVBnaWVQVGlVdksvQk4wVUlxZXRYT1dQUkErdkdjTg%253D%253D/R33Y2023N04A0535.pdf
doi: 10.23736/S1973-9087.23.08091-7

View at Publisher

20 Suri, A., Tang, S., Kargilis, D., Taratuta, E., Kneeland, B.J., Choi, G., Agarwal, A., (...), Rajapakse, C.S.

Conquering the Cobb Angle: A Deep Learning Algorithm for Automated, Hardware-Invariant Measurement of Cobb Angle on Radiographs in Patients with Scoliosis

(2023) *Radiology: Artificial Intelligence*, 5 (4), art. no. e220158. Cited 10 times.
https://pubs.rsna.org/doi/10.1148/ryai.220158
doi: 10.1148/ryai.220158

View at Publisher